भारत-जर्मन परियोजनाः
(एन.सी.ई.आर.टी.-जी.टी.जेड.)

मध्य प्रदेश और उत्तर प्रदेश में प्राथमिक और मिडिल विद्यालयों में समुन्नत विज्ञान शिक्षा

# पर्यावरणीय अध्ययन-विज्ञान पर शिक्षक पुस्तिका

## कक्षा 4


आर.एस. रस्तोगी
एस.एस. श्रीवास्तव
एस.के. श्रीवास्तव
वी.एस. कटियार
बी.बी. विश्वकर्मा
एच.के.एल. शाह
जे.सी. मिश्रा
एस.बी. गुप्ता
वाई.एस. डण्डोतिया
जी.आर. सरवाईकर
एच.ओ. गुप्ता

बी.के. शर्मा
(शैक्षिक दल समन्वयक)
कर्मशाला विभाग


राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद्
NATIONAL COUNCIL OF EDUCATIONAL RESEARCH AND TRAINING

# प्राक्कथन

कक्षा 4 के लिए शिक्षक पुस्तिका प्राथमिक स्तर पर पर्यावरणीय अध्ययन-विज्ञान में शिक्षण सामग्री श्रृंखला का एक अंग है। यह पुस्तिका रा.शै.अ.प्र.प. द्वारा भारत-जर्मन परियोजना शीर्षक "मध्य प्रदेश और उत्तर प्रदेश में प्राथमिक और मिडिल विद्यालयों में समुन्नत विज्ञान शिक्षा" के अन्तर्गत विकसित की गई है। इस परियोजना के मुख्य घटक हैं विज्ञान किट का विकास और निर्माण, मुद्रित शिक्षण सामग्री का विकास और अध्यापकों का प्रशिक्षण। परियोजना का समन्वयन और अनुवीक्षण रा.शै.अ.प्र.प. नई दिल्ली के कर्मशाला विभाग द्वारा किया जा रहा है। आशा की जाती है कि इससे इन राज्यों में प्राथमिक स्तर पर विज्ञान शिक्षण में गुणात्मक सुधार लाने के लिए ठोस आधार प्रस्तुत होगा। यह परियोजना हाल ही में राष्ट्रीय शिक्षा नीति-1986 (एन.पी.ई.) और कारवाई के लिए बनाये गए कार्यक्रम (पी.ओ.ए.) के अंतर्गत तैयार की गई योजनाओं को तकनीकी और तर्कसंगत समर्थन प्रदान करने के लिए निश्चित की गयी है। इस प्रकार "ऑपरेशन ब्लैक बोर्ड" (ओ.बी.) योजना के अंतर्गत प्राथमिक स्तर पर आवश्यक सुविधा प्रदान करने के लिए शिक्षक पुस्तिका, प्राथमिक विज्ञान किट और किट नियमावली सूचीबद्ध पैकेज के महत्वपूर्ण अंग के रूप में है। यह पुस्तिका राज्य विज्ञान शिक्षा संस्थान-इलाहाबाद, विज्ञान किट कर्मशाला-भोपाल, कर्मशाला विभाग रा.शै.अ.प्र.प. नई दिल्ली, के शैक्षिक दल के सदस्यों, जर्मन विशेषज्ञों और प्राथमिक विद्यालयों के अध्यापकों द्वारा किए गये सराहनीय टीम कार्य का परिणाम है। पहले वर्तमान पाठ्यचर्या संरचना, दिशानिर्देश, और "पर्यावरणीय अध्ययन-विज्ञान" के पाठ्य-विवरण का विभिन्न कोणों से विश्लेषण किया गया और इसके बाद विषय-वस्तु पर शिक्षण क्रियाकलापों का गठन, शैक्षणिक दल द्वारा किया गया। आशा की जाती है कि यह शिक्षक पुस्तिका वैज्ञानिक संकल्पनाओं के क्रमबद्ध विकास को आगे बढ़ाने के लिए पाठ्यपुस्तक का संपूरक होगी।

मैं जी.टी.जैड़, श्री वी. वाईसर, सलाहकार और जर्मन दल नेता, श्री एच.एच. प्रोवे, तकनीकी विशेषज्ञ और अन्य अल्पकालीन विशेषज्ञों को उनकी सहायता और सुविज्ञता के लिए धन्यवाद ज्ञापित करता हूँ। निदेशक, राज्य शैक्षिक अनुसंधान एवं प्रशिक्षण परिषद् (उ.प्र.), लखनऊ, निदेशक, रा.वि.शि.सं., इलाहाबाद, प्रधान सचिव, सी.पी.आई., डी.पी.आई. (म.प्र.) भोपाल भी, सहयोग प्रदान करने और गहन रूचि लेने के लिए धन्यवाद के पात्र हैं। मैं प्रो. पी.के. भट्टाचार्य, अध्यक्ष, कर्मशाला विभाग और उनके सहयोगियों का आभारी हूँ जिन्होंने परियोजना की योजना के प्रचालन के विभिन्न घटकों में समन्वयन और कार्यान्वयन किया है। मैं डा.बी.के. शर्मा जिन्होंने परियोजना के शैक्षणिक कार्यकलापों का समन्वयन और अनुवीक्षण किया है, को, उनके समीक्षात्मक पुनरीक्षण और पांडुलिपि को अन्तिम रूप देने हेतु धन्यवाद देता हूँ। मैं लेखन दल के सभी सदस्यों, विषय विशेषज्ञों, पुनरीक्षकों और प्रतिभागी शिक्षकों और जिन संस्थानों से वे सम्बन्धित है, का भी, उनके योगदान के लिए आभारी हूँ।

मैं आशा करता हूँ कि प्राथमिक विद्यालय शिक्षक, इस पुस्तिका को अपने लिए उपयोगी और रूचिकर पाएगें। पुस्तिका में और अधिक सुधार लाने के लिए दिए गये सुझावों और विचारों का स्वागत है। पुस्तिका के वर्तमान संस्करण का संशोधन करते समय परिषद् इस प्रकार के सुझावों और विचारों पर गम्भीरतापूर्वक विचार करेगी।

नई दिल्ली
17 नवम्बर, 1988

पी.एल. मल्होत्रा
निदेशक
राष्ट्रीय शैक्षिक अनुसंधान और
प्रशिक्षण परिषद्

## आमुख

प्राथमिक स्तर पर पर्यावरणीय अन्वेषण हेतु छात्र-केन्द्रित तथा क्रिया-आधारित उपागम की संस्तुति की गई है। इस प्रकार का उपागम आत्मविश्वास, विवेक पूर्ण दृष्टिकोण, जिज्ञासा, अन्वेषण भावना, सर्जनात्मकता, वस्तुनिष्ठता, प्रश्न पूछने का साहस, पहल शक्ति और सत्य तथा सौंदर्य परक मूल्यों की सराहना जैसी अभिवृत्तियों एवं गुणों के विकास में पर्याप्त अवसर प्रदान करेगा। इससे दैनिक जीवन यापन और पर्यावरणीय परिस्थितियों में सुधार लाने के लिए जीवन में तर्कसंगत एवं स्वतंत्र चिन्तन, प्रेक्षण, तर्कशक्ति, विश्लेषण, व्याख्या, समस्या समाधान एंव निर्णय जैसे कौशलों के संवर्धन में सहायता मिलेगी। इस संदर्भ में अध्यापक की भूमिका बहुत महत्वपूर्ण है। अध्यापकों को मात्र वैज्ञानिक ज्ञान देने और इसका प्रसार करने की अपेक्षा क्रिया को सरल बनाना चाहिए, अन्वेषण में सहायक होना चाहिए तथा सीखने सम्बन्धी संसाधनों को पहचाननें में मार्गदर्शक का रूप अपनाना चाहिए। सीखने की परिस्थितियों का सर्वाधिक लाभ प्राप्त करने के लिए शिक्षण सामग्री के रूप में शिक्षक पुस्तिका की नितान्त आवश्यकता है, जिससे अध्यापकों को सीखने, सिखाने की प्रक्रिया को अधिक लचीला बनाने में सहायता मिलेगी।

यह पुस्तिका अध्यापकों की नई भूमिका तथा प्राथमिक विद्यालय के शिक्षकों एवं शिक्षक-प्रशिक्षकों के सेवाकालीन और सेवा पूर्व प्रशिक्षण को ध्यान में रखते हुए विकसित की गई है। यह पुस्तिका चार भागों में विभाजित है। प्रथम भाग में इसके उपयोग विधि से सबन्धित सामान्य अनुदेश दिए गए हैं। इसके बाद के दो भागों में विज्ञान सीखने के उपागम एवं उपलब्ध स्थानीय सामग्री का उपयोग बताया गया है। चौथे भाग में छात्र-केन्द्रित क्रिया कलापों के विवरण पर प्राथमिक अध्यापकों को इकाई के अनुसार व्यापक अनुदेश दिए गए हैं। छात्र इस पुस्तिका में दिए गये अधिकांश क्रियाकलापों को प्राथमिक विज्ञान किट में उपलब्ध वस्तुओं की सहायता से आसानी से कर सकते हैं। छात्र के पर्यावरण सम्बन्धी प्रेक्षण पर आधारित क्रिया कलाप-स्थानीय उपलब्ध सामग्री के उपयोग से किए जा सकते हैं। तथापि, प्राथमिक विज्ञान किट की कुछ वस्तुओं की आवश्यकता पड़ सकती है। इस शिक्षक पुस्तिका का विकास अनेक स्तरों पर किया गया है। सर्वप्रथम राज्य विज्ञान शिक्षा संस्थान, इलाहाबाद, विज्ञान किट कर्मशाला, भोपाल और कर्मशाला विभाग, रा.शै.अ.प्र.प., नई दिल्ली, में स्थापित शैक्षिक दल के सदस्यों द्वारा, रा.शै.अ.प्र.प. तथा इन राज्यों में तैयार पाठय चर्या संरचना, दिशा निर्देश, पाठ्य विवरण तथा अन्य सामग्री का विश्लेषण किया गया। तत्पश्चात अधिगम परिणाम, प्रस्तावित शिक्षण प्रक्रम और साधन एवं सामग्री सहित प्रारूप का विकास किया गया। तकनीकी दल ने प्रथमतः प्राथमिक विज्ञान किट के समानांतर प्रथम "प्रोटोटाइप" विकसित किया। दोनों टीमों के मध्य निरन्तर पारस्परिक संपर्क बनाए रखा गया। इस शिक्षक पुस्तिका और प्राथमिक विज्ञान किट को, पहले कृत्रिम परिस्थितियों में तथा बाद में उ.प्र., म.प्र. और दिल्ली के चुने हुए प्राथमिक विद्यालयों में परीक्षण के बाद ही अंतिम रूप दिया गया। पांडुलिपि के प्रारूप को परियोजना से सम्बन्धित समस्त शिक्षाविदों एवं इस क्षेत्र में कार्यरत कुछ संगठनों और संस्थाओं को भेजा गया। इस प्रकार परीक्षण से प्राप्त परिणामों एवं पुनर्निवेशन पर विचार विमर्श किया गया, उनका विश्लेषण किया गया और उन्हें शिक्षक पुस्तिका के अन्तिम रूपान्तर में समाविष्ट किया गया। इस शिक्षक पुस्तिका और प्राथमिक विज्ञान किट के विकास तथा परीक्षण में शहरी और ग्रामीण दोनों क्षेत्रों के प्रतिनिधि अध्यापकों ने भाग लिया। इनमें विज्ञान और विज्ञानेतर-दोनों पृष्ठ भूमि वाले, अध्यापक सम्मिलित हुए।

हम श्री एच. हर्टमैन, श्री बर्ग मैन और डा. एच. बेयर के प्रति आभार व्यक्त करते हैं जिन्होंने इस परियोजना संगोष्ठी नियोजन में महत्वपूर्ण योगदान दिया। हम डा. लॉटर बैंक और डा. स्कोएनहर का धन्यवाद करते हैं जिन्होंने शिक्षण और अध्यापक प्रशिक्षण सामग्री तैयार करने में सहायता दी। हम म.प्र. और उ.प्र. के 252 प्राथमिक विद्यालयों में सर्वेक्षण हेतु श्रीमति आई.वास एवं शिक्षक-पुस्तिका के प्रथम प्रारूप सहित परियोजना के परिणामों के मूल्यांकन हेतु श्री स्मिट, डा. रौठ तथा प्रो. आर.एन. मेहरोत्रा के आभारी हैं। विज्ञान शिक्षा संस्थान, कील (संघीय जर्मन गण राज्य) के डा. आर. लॉटरबक के व्याख्यान एवं परामर्श, इस पुस्तिका के लेखन दल के सदस्यों हेतु बहुत लाभदायक पाए गए।

हम प्रो. पी.एल. मल्होत्रा, निदेशक, प्रो. ए.के. जलालुद्दीन, संयुक्त निदेशक, रा.शै.अ.प्र.प., का सक्रिय रूप से मार्गदर्शन प्रदान करने के लिए धन्यवाद व्यक्त करते हैं। प्रो.पी.एन. दवे, अध्यक्ष, डी.पी. एस.ई.ई., प्रोफेसर बी. गांगुली, अध्यक्ष, डी.ई. एस.एम. और प्रो. ए.के. शर्मा, अध्यक्ष, डी.टी.ई. एस.ई. एवं ई.एस. और उनके सहयोगियों द्वारा दिए गए सुझावों के लिए धन्यवाद देते हैं। हम कर्मशाला विभाग के सहयोगियों, लेखक दल, संपादकों, सलाहकारों, प्रतिभागी अध्यापकों तथा उनकी संस्थाओं के आभारी हैं जिनके परिश्रम से यह प्रकाशन संभव हुआ। हमें आशा है कि प्राथमिक विज्ञान शिक्षा से सम्बद्ध शिक्षकों और शिक्षक-प्रशिक्षकों के लिए यह पुस्तिका उपयोगी सिद्ध होगी। इस पुस्तिका में और अधिक सुधार हेतु सम्बन्धित सुझावों का स्वागत है।

वी. वाईसर
शैक्षिक परामर्शदाता एवं
जर्मन दल नेता
नई दिल्ली
11 नवम्बर, 1988

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# विषय सूची

## इकाई 7: पृथ्वी और आकाश



(आकाश और पृथ्वी)

7.1 ग्रह और उपग्रह एक दूसरे से किस प्रकार भिन्न हैं?

7.2 प्राकृतिक उपग्रह कृत्रिम उपग्रहों से किस प्रकार भिन्न हैं?

7.3 हम चन्द्रमा की कलाओं का संबंध उसके द्वारा की गई पृथ्वी की परिक्रमा से कैसे सम्बन्धित करते हैं?

7.4 दिन और रात कैसे होते हैं?

7.5 क्या पृथ्वी के परिभ्रमरा के कारण ऋतुएँ होती है?

7.6 क्या हमारे त्यौहार, सांस्कृतिक गतिविधियाँ और भारतीय कलेण्डर (पंचांग) आकाशीय पिण्डों से संबंधित हैं?

## 1. इस पुस्तिका का उपयोग कैसे करें?

इस पुस्तिका का उद्देश्य कक्षा 4 की विज्ञान की पाठ्यपुस्तक (पर्यावरणीय अध्ययन) की विभिन्न इकाइयों के लिए शिक्षार्थी-केन्द्रित विभिन्न क्रियाकलाप प्रदान करना है। इन क्रियाकलापों का अभिप्राय छात्रों को स्वयं के प्रेक्षणों द्वारा पर्यावरण की छान बीन करने के लिए प्रोत्साहित करना है। पुस्तिका में ऐसे क्रियाकलापों का उल्लेख है जिनमें से अधिकांश को प्राथमिक विज्ञान किट में उपलब्ध वस्तुओं से सम्पन्न किया जा सकता है। कुछ क्रियाकलापों को सम्पन्न करने में किट की आवश्यकता शायद न भी हो क्योंकि वे शिक्षार्थी के अनुभवों पर आधारित हैं। प्रत्येक इकाई में प्रश्न के रूप में समस्यामूलक प्रकरणों का समावेश है जिनके लिए 1.1, 1.2 आदि संख्याओं का प्रयोग किया किया गया है। प्रत्येक प्रकरण से सम्बन्धित क्रियाकलापों के लिए 1.2.1, 1.2.2, 1.2.3, आदि संख्याओं का प्रयोग किया गया है। उदाहरणार्थ 1.2.3 का अर्थ है इकाई 1, उपइकाई 2, क्रियाकलाप 3 तथा 1.6. विस्तारण 2 का अर्थ है इकाई 1, उपइकाई 6 तथा विस्तारण 2 कुछ प्रकरणों से संबंधित क्रियाकलापों को सम्पन्न करने के लिए यह नितांत आवश्यक होगा कि इसकी तैयारी पहले से कर लें। विभिन्न प्रकरणों से सम्बन्धित क्रियाकलापों के लगातार कई कालांश तक चलने तथा किसी प्रकरण/क्रियाकलाप के परिणामों को अन्य क्रियाकलापों के उपयोग में लाने के लिए, सुझाव भी दिए गए हैं। विभिन्न क्रियाकलाप सम्पन्न करके प्रकरण पूरा करने के लिए अनुमानित समयावधि भी प्रस्तावित है। यदि आपकी रुचि आतिरिक्त क्रियाकलाप सम्पन्न करने में है तो इसके लिए आप स्वतंत्र हैं।

क्रियाकलापों को सम्पन्न करने में आप द्वारा मार्गदर्शन किया जाय तथा सम्बोधों के क्रमागत विकास को सरल बनाया जाए.,इस दृष्टि से उद्देश्यों एवं संरचनात्मक सोपानों का भी सुझाव दिया गया है। क्रियाकलापों की अवधि में प्रोत्साहित करने के लिए प्रश्न तथा उनमें से कठिन प्रश्नों के उत्तर (आवश्यकतानुसार) संकेत सहित दिए गए हैं। किसी क्रियाकलाप को सम्पन्न करने के लिए आवश्यक साधन तथा सामग्री का भी उल्लेख है। साधन और सामग्री के स्तम्भ में किट की वस्तुओं को लाल अक्षरों में अंकित किया गया है। यदि आपकी समझ से किसी विशेष क्रियाकलाप को स्थानीय साधनों से उपलब्ध सामग्री से किया जा सकता है तो आप इन वस्तुओं का उपयोग करके उसे कर सकते हैं। स्थानीय साधनों से उपलब्ध सामग्री की सूची एक अलग अनुच्छेद 3 में दी गई है। छात्रों द्वारा प्रेक्षणों के उचित अभिलेखन और उनसे निष्कर्ष निकालने के लिए आवश्यक तालिका आपकी सहायतार्थ उदाहरण सहित दी गई है। आप सारणियों को छात्रों द्वारा पूरी कराएं। अधिकांश क्रियालापों के बाद परियोजना कार्य, क्षेत्र-भ्रमण, सामूहिक विचार विमर्श, संकलन, चित्रांकन आदि के रूप में विस्तारण क्रियाकलाप दिए गए हैं। विस्तारण, क्रियाकलापों में आप स्थानीय परिस्थितियों एवं साधनों से उपलब्ध सामग्री के अनुसार संशोधन कर सकते हैं अथवा उनमें कुछ जोड़ सकते हैं।

## 2. विज्ञान अधिगम उपागम

विगत वर्षों में वैज्ञानिक ज्ञान में द्रुत गति से वृद्धि हुई है। मानव विचार, सामाजिक मूल्य, रीति एवं संस्कृति में परिलक्षित विज्ञान शिक्षा की आवश्यकता के परिप्रेक्ष्य में जीवन की गुणवत्ता में सुधार लाने के लिए विज्ञान पाठ्यक्रम तथा विज्ञान अधिगम उपागम का आधुनिकीरण अपरिहार्य हो गया है। राष्ट्रीय शिक्षा नीति (1986) के अनुसार किसी शिक्षार्थी को वैज्ञानिक दृष्टि से साक्षर नागरिक बनाने के लिए

— विज्ञान के मूल सम्बोधों को समझना तथा इनका अनुप्रयोग करना,
— वैज्ञानिक विधि से जांच और सूचना एकत्र करने के लिए आवश्यक कौशल प्राप्त करना,
— वांछित अभिवृत्ति, सत्यता का मूल्य एवं वस्तुनिष्ठता का विकास करना,
— सर्जनात्मक क्षमता का पोषण करना
— दैनिक जीवन, पर्यावरणीय परिस्थितियों तथा तकनीकी विकास और अनुप्रयोग के उन्नययन के लिए वैज्ञानिक पद्धति में निपुणता प्राप्त करना और इसका समस्या समाधान में उपयोग करने के लिए निर्णय लेने की क्षमता का विकास करना नितांत आवश्यक है।

उपर्युक्त उद्देश्यों की पूर्ति हेतु यह आवश्यक है कि स्मृति और विषय वस्तु से सम्बद्ध शिक्षक-केन्द्रित शिक्षण विधि पर बल देने के स्थान पर

— समस्या समाधान आधारित,
— क्रियाकलाप आधारित,
— और शिक्षार्थी-केन्द्रित उपागमों पर बल दिया जाय।

इसके लिए शिक्षार्थियों को

— छानबीन करने,
— प्रेक्षणों के अभिलेखन करने,
— सूचनाओं के सम्प्रेषण, इनकी संरचना एवं व्याख्या करने
— परिकल्पना बनाने,
— आंकड़ों को संकलित एवं विश्लेषित करने
— प्रासंगिक निष्कर्ष निकालने,
— समस्या के हल की रूपरेखा तैयार करने एवं इसके अनुसार कार्य करने में सम्मिलित करना अपेक्षित है।

चिन्तन और तर्क-वितर्क करने तथा समस्या समाधान हेतु विज्ञान को, एक उच्चकोटि के विवेक पूर्ण, बौद्धिक मानवीय क्रियाकलाप के रूप में समझने का यह पर्याप्त अवसर प्रदान करता है। यह जीवन की वास्तविक परिस्थितियों एवं समस्याओं के परिप्रेक्ष्य में, आत्मविश्वास, जिज्ञासा, नेतृत्व, स्वावलम्बन, अध्यवसाय तथा अभिनव कौशल विकसित करने में सहायक हैं। इन वैज्ञानिक प्रक्रियाओं तथा कौशलों द्वारा सम्बोधों का क्रमिक विकास किया जा सकता है। तथापि अधिगम परिस्थितियों का सर्वोत्तम उपयोग करने के लिए यह नितांत आवश्यक है कि शिक्षक को पाठ्य पुस्तकों के अतिरिक्त शिक्षण सामग्री भी प्रदान की जाय। किसी छान बीन के लिए आपको पहले से ही उसकी योजना तथा सामान्य रूपरेखा

बना कर पर्याप्त तैयारी कर लेनी चाहिए। पाठ्य पुस्तक तथा इस पुस्तिका से सम्बन्धित विषय वस्तु का आप अध्ययन कर उसमें निहित वैज्ञानिक, विचारों, उनके दैनिक जीवन में अनुप्रयोग और छानबीन द्वारा विकसित की जाने वाली अधिगम प्रक्रियाओं का विवरण तैयार कर लें। इस पुस्तिका में आपकों शिक्षार्थी केन्द्रित अधिगम अनुभवों तथा क्रियाकलापों के विवरण के रूप में आवश्यक शिक्षण सामग्री प्रदान करने का प्रयास किया गया है। इस में किट की वस्तुओं के उपयोग तथा शिक्षार्थी के स्वयं के अनुभवों के आधार पर अनुसंधान हेतु संकेत और आवश्यक प्रायोगिक कौशलों का भी समावेश किया गया है। पुस्तिका में प्रस्तावित क्रियाकलापों का कक्षा में जाने से पूर्व पूर्णपरीक्षण आवश्यक है। उपलब्ध स्थानीय संसाधनों द्वारा भी आप छानबीन कर सकते हैं।

प्रस्तुत विज्ञान अधिगम उपागम द्वारा आप को ऐसा अवसर उपलब्ध होता है, जिसके अन्तर्गत शिक्षक के रूप में आपको मात्र वैज्ञानिक ज्ञान के सम्प्रेषक के रूप में ही नहीं अपितु क्रियाकलापों के सम्पन्न करने में एक सहायक और सह-अनुसंधाता के रूप में भी कार्य करना है। इस प्रकार आप सह शिक्षार्थी भी रहेंगे।

पर्यावरण को एक संसाधन के रूप में प्रयोग करते हुए शिक्षार्थी के स्वयं के अनुभव, अन्वेष्णात्मक समस्या समाधान उपागम तथा स्वयं करके सीखने और क्रिया पक्ष पर आप द्वारा विशेष बल दिया जाना अपेक्षित है। प्राथमिक विज्ञान किट अथवा स्थानीय संसाधनों से उपलब्ध सामग्री के उपयोग द्वारा उचित अधिगम परिस्थितियां उत्पन्न करने के लिए शिक्षार्थियों को, प्रोत्साहन दें।

शिक्षार्थी केन्द्रित उपागम के अन्तर्गत सभी क्रिया कलापों को स्वयं अथवा छोटे-छोटे समूहों में सम्पादित करें तो श्रेयस्कर होगा। सम्भव है कि आपको प्राथमिक विज्ञान किट में उपलब्ध वस्तुओं की सीमित संख्या के कारण कुछ प्रकरणों पर सम्पूर्ण कक्षा के समक्ष प्रयोग प्रदर्शित करना पड़े। उचित अधिगम परिस्थितियों व्यक्तिगत या छोटे समूह में छात्रों द्वारा छानबीन विचार-विमर्श या परियोजना कार्य सम्पन्न करने में तथा रटने की प्रवृति कम करने और स्वतंत्र चिन्तन को प्रोत्साहित करने में सहायक होती है।

किसी क्रियाकलाप की अवधि के विभिन्न चरणों एवं अनुक्रमों की सुविचारित एवं कौशलपूर्ण प्रेक्षण एक रोचक अनुभव तथा खोज विधि का प्रमुख अंग है। दैनिक जीवन में रहन-सहन ओर पर्यावरण की दशा सुधारने तथा तकनीकी के अनुप्रयोग के प्रोत्साहन हेतु छात्रों को आत्म-विश्वासी बनाने, स्वतंत्र रूप से समस्या का समाधान करने में सक्षम बनाने के लिए, छानबीन की अवधि में आपको उपयुक्त प्रश्न पूछना चाहिए।

यदि किसी क्रियाकलाप को पूरा करने में सफलता न मिले तो आप हतोत्साहित न हों। ऐसी परिस्थिति में छात्रों के साथ असफलता के कारणों का विश्लेषण कीजिए और अधिकतम तर्कसंगत सुझाव के अनुसार पुनः परीक्षण करें। यदि फिर भी सफलता न मिले तो वैकल्पिक योजना बना कर क्रियाकलाप के सफल होने तक परीक्षण करते रहिये। किसी क्रियाकलाप की अवधि में इससे सम्बन्धित प्रक्रम को नियंत्रित करने वाले विभिन्न चरणों की खोज विधि के रूप में बार-बार दोहराने से शिक्षार्थी नई खोज में लगे एक उभरते हुए वैज्ञानिक, नया अनुसंधान करते हुए अभियंता अथवा नवीन चित्रांकन का सृजन करते हुए एक चित्रकार की तरह, सम्पूर्ण प्रक्रिया को भलीभांति समझने में समर्थ हो जाता है।

कक्षा के बाहर सम्पन्न किए जाने वाले क्रियाकलापों के रूप में आप क्षेत्रीय भ्रमण तथा बाह्य परियोजनाओं का आयोजन कीजिए। ताकि छात्र बाहर जा कर पर्यावरण को समझने के अवसर प्राप्त करें, क्योंकि दर्शन, श्रवण, घ्राण एवं स्पर्श अनुभव के आधार पर ज्ञान प्राप्त करना अधिगम का एक बहुत रोचक तथा शिक्षाप्रद ढंग है। छात्रों को व्यक्तिगत रूप में अथवा छोटे समूह में पर्यावरणीय वनस्पति तथा जीव जन्तु के प्रेक्षण हेतु निर्दिष्ट कीजिए। उनके अनुभवों को कक्षा में प्रस्तुत करने एवं इनका आदान प्रदान करने के लिए उनका आह्वान कीजिए। छात्रों के जीवन्त विचार विमर्श में आपका सक्रिय प्रतिभाग अपेक्षित है।

श्रव्य-दृश्य साधन अधिगम में सहायक होते हैं। श्यामपट्ट पर बनाए गए बड़े चित्रों की सहायता से छात्रों को प्रभावी ढंग से समझाया जा सकता है, इसलिए श्यामपट्ट भी एक महत्वपूर्ण साधन हैं। अधिगम हेतु अपने विचारों को स्पष्ट करने में श्यामपट्ट के अधिकाधिक प्रयोग के लिए छात्रों को प्रोत्साहित कीजिए।

आप से अपेक्षा की जाती है कि आप विज्ञान किट में उपलब्ध चार्टों का उपयोग प्रभावी ढंग से करें। आपको, अधिगम हेतु उचित एवं अर्थपूर्ण क्रियाकलापों जैसे चार्ट बनाना, साधारण एवं निर्मूल्य प्रतिमान बनाना, पत्रिकाओं और समाचार पत्रों से संकलन करना आदि को सम्पन्न करने के लिए छात्रों को प्रोत्साहित करना चाहिए। यह अतिरिक्त अधिगम हेतु उचित लक्ष्य प्राप्त करने में सहायक होगा।

## 3. स्थानीय साधनों से उपलब्ध वस्तुओं का उपयोग

बहुत सी वस्तुएं या तो रद्दी में पाई जाती हैं या निमूल्य अथवा कम मूल्य पर स्थानीय साधनों से उपलब्ध हैं। इनका उपयोग कक्षा के क्रियाकलापों को प्रदर्शित करने के लिए उपकरणों के निर्माण के लिए किया जा सकता है। ऐसी वस्तुओं की सूची कुछ प्रयोगों/उपकरणों के विवरण के साथ नीचे दी जा रही है। तथापि इस सूची में, आप किसी अन्य उपयुक्त वस्तु को सम्मिलित कर सकते हैं।

### क. स्थानीय साधनों से उपलब्ध वस्तुओं की सूची

1. बाल्टी/कनस्तर
2. प्लास्टिक के पात्र/कॉच की बोतल
   (मिट्टी के तेल में भीगे हुये धागे को बोतल के चारों और उचित स्थान पर लपेट कर और फिर धागे को जला कर बोतल को काट कर इसका उपयोग गिलास के रूप में किया जा सकता है)
3. फ्यूज़ विद्युत बल्ब, आवर्धक लैन्स की तरह और गर्म करने के लिए पात्र के रूप में
4. माचिस के डिब्बे विभिन्न पदार्थों अथवा बाटों को रखने के पात्र के रूप में
5. चम्मच
6. रबर बैन्ड

7. रबर के गुब्बारे
8. धागा/फीता
9. कागज/प्लास्टिक की थैलियां
10. डिब्बे
11. छोटा दर्पण/कांच की शीट/ऐलुमिनियम की पन्नी/सेलोफेन का कागज/चार्ट का कागज
12. गमला, पात्र के रूप में
13. बेकार पिचकारी द्रव मापन के लिए और ड्रापर की तरह
14. सरकण्डे, विभिन्न प्रकार की आकृतियां और प्रतिमान बनाने के लिए
15. विभिन्न प्रकार के कपड़ों के कतरन, शिल्प कार्य और गुडिया बनाने के लिए
16. मोमबत्ती
17. मिट्टी का गेंद, बॉट/शिल्प सामग्री के रूप में
18. रबर गेंद
19. मिट्टी के पात्र
20. दवा डालने वाला ड्रापर
21. कांटे, काटने/वस्तुओं को जड़ने के लिए
22. कील, पेंच, तार/तार की जाली
23. धावन सोडा
24. शक्कर
25. साधारण नमक
26. मिट्टी के तेल का बर्नर
27. स्याही और रंग/पेन्ट
28. बीज
29. पत्तियां
30. शंख/नारियल का कवच
31. पक्षियों के घोंसले
32. स्थानीय चट्टान, खनिज पदार्थ
33. टूटे हुए चुम्बक
34. पाउडर के खाली डिब्बे
35. जाटर रिफिल, फूँकने वाली नली के रूप में

36. बोतलों के ढक्कन, छोटे पात्र के रूप में
37. अगरबत्ती

## खः वस्तुओं का निर्माण

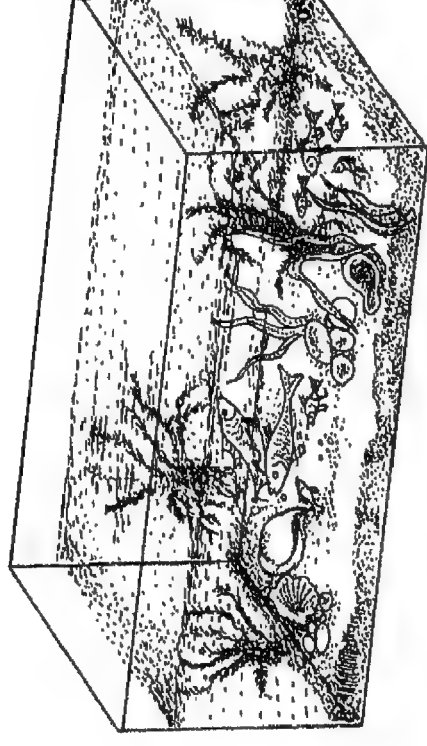
### ख 1 जल जीव शाला तैयार करना

**उद्देश्यः** जलीय जीव तथा पौधों के लिए जल जीवशाला के द्वारा उन्हें एक पर्यावरण प्रदान किया जाता है। कक्षा में जलीय जीव तथा पौधों को लाने की यह एक मनोहर विधि है। यह बच्चों को मछलियाँ, पेड़-पौधे, घोंघा, भेक-शिशु तथा कछुआ आदि को निरीक्षण तथा खोज का अवसर प्रदान करता है।

**आवश्यक सामग्रीः** एक खाली तेल का पीपा/छोटी कनस्तरी, रेत, जलीय पौधे जो स्थानीय तालाबों में उपलब्ध हैं (जलीय पौधे), जलीय जन्तु, टिन कटर, सरेस, प्लास्टिक की चद्दर/पालीथीन की थैलियाँ

**बनाने की विधिः** एक साफ किए गए पीपे के विमुख फलकों के प्रत्येक ओर उचित आकार की खिड़की काटिए। ऊपरी फलक भी चित्रानुसार काटा जा सकता है। पीपे को ठीक से जाँच कीजिए कि वह रिसता न हो अन्यथा उसे सरेस से बंद कर दीजिए। मुख भाग को हटाए जा सकने वाले पारदर्शक प्लास्टिक की चद्दर या पालीथीन की थैलियों से ढ़क दीजिए। वायु के आवागमन के लिए छोटे-छोटे छिद्र रहने दीजिए। ठीक से साफ किया हुआ बालू तथा कंकड़ से पीपे की पेंदी को ढ़क दीजिए। लगभग आधे से कुछ अधिक भाग जल से भर दीजिए। जल, रसायनों से मुक्त हो (क्लोरीन, आदि)। यदि यह उपस्थित हों तो जल को दो-तीन दिन तक भरने से पहले स्थिर रहने दीजिए। जलीय पादप (पौधा) डालिए (कैरा, हाइड्रिला, बैलिसनिरिया उपयुक्त होगा)। छोटी जड़ों एवं पत्तियों वाले पादप चुनिए। जड़ों को फैलाइये और बालू में दबा दीजिए। जल जीवशाला तैयार है। अब कुछ मछलियाँ, घोंघें, कछुए आदि उसमें डालिए। जल जीवशाला को इस प्रकार से रखिए कि इसे उचित प्रकाश मिले लेकिने सीधा प्रकाश न पड़े।

### मछलियों का पोषण

मछलियों को बहुत थोड़े भोजन की आवश्यकता होती है। कृमि सबसे उत्तम होते हैं। फैरेक्स, सलाद, रोटी के कण, अण्डे की जर्दी (कड़ा उबला हुआ) उपयोग किया जा सकता है। 6-8 मछलियों के लिए प्रतिदिन हेतु एक चुटकी भोजन प्रचुर होगा। मछलियाँ अधिक खाने से मर जाती हैं। मछलियाँ बिना भोजन के सात दिन तक जीवित रह सकती हैं।

**जल जीवशाला की स्वच्छता**

एक छन्नी की सहायता से मछलियों को जल जीवशाला से बाहर निकालिए और एक दूसरे पात्र के जल में डाल दीजिए। पीपे का जल, साइफन विधि से अथवा मग से बाहर निकाल दीजिए। बालू, पत्थर, पौधों को साबुन तथा जल से साफ कर दीजिए। साबुन का प्रभाव ठीक से समाप्त कर देना चाहिए। शैवाल को, रेजर के ब्लैड से खुरच करके और नमक से कपड़े को भिगो करके साफ किया जा सकता है।

**ख 2 निस्यंदन**

**आवश्यक सामग्रीः** तार, हरे बांस की छड़ी, कपड़े का टुकड़ा, बीकर

**बनाने की विधिः** तार या हरे बांस की छड़ी से लगभग 5 से.मी. व्यास का एक छल्ला बनाइए और उसके चारों ओर एक कपड़ा बांध दीजिए। आप का निस्यंदन• उपकरण तैयार है।

## 4. क्रियाकलापों का विवरण

इस अनुच्छेद में आपको सात इकाईयों-सजीव वस्तुएँ मानव शरीर, पोषण तथा स्वास्थ्य; पदार्थ और उनके गुण; वायु, जल और मौसम, मृदा और फसलें; बल, कार्य तथा ऊर्जा; पृथ्वी और आकाश, के विषय में शिक्षार्थी-केन्द्रित अधिगम अनुभवों से संबंधित आवश्यक जानकारी उपलब्ध कराने का प्रयास किया गया है। आशा है कि सुझाए गए ये क्रियाकलाप शिक्षार्थियों को उनके दैनिक जीवन के अनुभवों एवं प्रेक्षणों द्वारा पर्यावरण की छानबीन के लिए पर्यावरण

एवं किट के सामानों से विभिन्न क्रियाकलापों को सम्पन्न करने के लिए आवश्यक अन्वेषण केन्द्र बिन्दु एवं प्रायोगिक कौशल प्रोत्साहन करेंगे । क्रियाकलापों को कक्षा की वास्तविक परिस्थितियों में करने के पूर्व आपको इनका इस अनुच्छेद में दिए गए सुझावों के अनुसार परीक्षण कर लेना चाहिए ।

## इकाई 1: सजीव वस्तुएँ

(पौधे के विभिन्न भागों के कार्य; जन्तुओं और पौधों के उपयोग; जन्तुओं और पौधों की देखभाल की सुरक्षा)

**प्रस्तावना**

कक्षा-3 में छात्र सजीव एवं निर्जीव वस्तुओं के विभिन्न लक्षणों के अंतरों से अवगत हो चुके हैं । वे पहचान सकते हैं कि पौधे भी सजीव वस्तुएँ है, यद्यपि पौधे एक स्थान से दूसरे स्थान तक गति (सक्रिय) या कोई ध्वनि उत्पन्न नहीं करते हैं ।

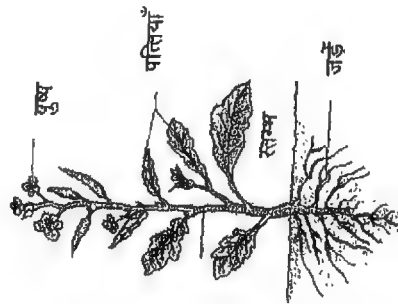
इस इकाई में छात्रः

- पौधे अपने आपको भूमि में जड़ों के सहारे कैसे स्थिर रखते हैं, को जानने,
- पौधा जड़ के द्वारा भूमि से जल एवं खनिज कैसे प्राप्त करता है, को समझने,
- तना संवहन का कार्य करता है; और वह जड़ों द्वारा अवशोषित जल को पौधे के विभिन्न भागों में पहुँचाता है, को जानने,
- हरी पत्तियाँ पौधे के लिए भोजन बनाती हैं, को समझने,
- अधिकांश पौधे फल एवं बीज उत्पन्न करते हैं, की पहचान करने,
- पौधों के बीजों से नए पौधे उत्पन्न होते हैं, को समझने,
- सतत स्वस्थ पीढ़ी बनाए रखने के लिए बीजों को मातृ पौधे से दूर प्रकीर्णन होना आवश्यक है, को समझने,
- पौधे हमारे लिए विभिन्न प्रकार से उपयोगी हैं, को पहचानने,
- जन्तुओं की सुरक्षा एवं देखभाल की आवश्यकता होती है, को समझने,
- किस प्रकार जन्तु हमारे लिए उपयोगी हैं, को पहचानने,
- पौधों को भी जन्तुओं के समान सुरक्षा एवं देखभाल की आवश्यकता होती है, को समझने, में समर्थ होंगे ।

**1.1: पौधा अपने आपको भूमि में कैसे स्थिर रखता है?**
**केंद्रित करें: जड़ें पौधों को मजबूती से भूमि में स्थिर रखती हैं**

(कालांश 2-3)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| पहचानना कि जड़ें पौधे को भूमि में मजबूती से जकड़े रखती हैं | क्रियाकलाप 1<br>एक सपुष्पी पौधे के चित्र/चार्ट को दिखाओ और छात्रों से उसके विभिन्न भागों के नाम पूछिए<br>छात्रों से कहिए कि वे आस-पास से एक घास या खरपतवार का पौधा उखाड़ें।<br>उनसे पूछिए:<br>क्या इसको उखाड़ने के लिए तुम ने बल लगाया है?<br>पौधों की जड़ों पर तुम क्या देखते हो? | सपुष्पी पौधे का चित्र/चार्ट<br>घास या खरपतवार का पौधा, चाकू या कैंची |

पुष्प
पत्तियाँ
स्तम्भ
जड़ें

सपुष्पी पौधों

स्थिर पौधा

उखड़ा पौधा

अब जड़ को काटकर इस पौधे को भूमि में पुनः लगाइए ।
अब इस पौधे को पुनः उखाड़िए

बिना जड़ों का पौधा

बिना जड़ों का पुनः लगा पौधा

उनसे पूछिए:
क्या तुम इस पौधे को सरलता से उखाड़ सके हो?
पौधों की जड़ों पर तुम क्या देखते हो?
तुमनें जड़ सहित और बिना जड़ के पौधे उखाड़ने में क्या अंतर पाया?
यह निष्कर्ष निकालने में उनकी सहायता कीजिए कि जड़ें पौधे को भूमि में मजबूती से जकड़े रहती हैं ।

क्रियाकलाप 2

एक बीकर लीजिए । उसमें कुछ गीली रूई रखिए और उसमें मूँग या चने के बीज उगाइए । दो या तीन दिन के पश्चात् बीज अंकुरित हो जाए तो उनका निरीक्षण कीजिए ।
इन बीजों को अपने हाथ से या चिमटी की सहायता से निकालने का प्रयास कीजिए ।
जब हम इनको निकालेंगे तो कुछ रूई के रेशे इनकी जड़ों में लगे हुए आएँगे ।

बीकर, रूई, मूँग या चने के बीज, पानी, चिमटी

खाली मिट्टी का बर्तन/आइसक्रीम कप, बाग की मिट्टी

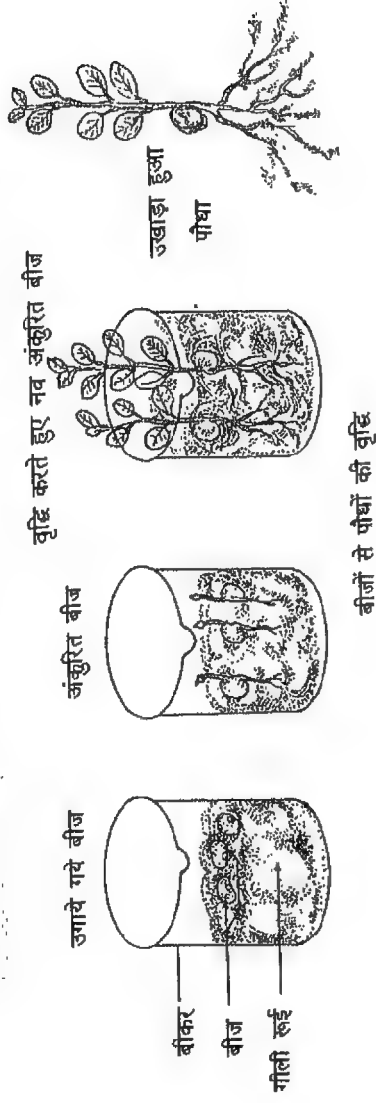
उनसे पूछिए:
जड़ों के साथ रूई के रेशे क्यों आ गए?
यह निष्कर्ष निकालने में उनकी सहायता कीजिए कि जड़ें पौधों को रूई में भी उसी प्रकार मजबूती से पकड़े रहती हैं जिस प्रकार भूमि को।

उगाये गये बीज

बीकर

बीज

गीली रूई

वृद्धि करते हुए नव अंकुरित बीज

बीजों से पौधों की वृद्धि

**विस्तारण 1**

क्रियाकलाप 1.1.2 करने के लिए, बीकर के स्थान पर छात्रों को मिट्टी का खाली बर्तन/आइसक्रीम कप, तथा रूई के स्थान पर बाग को मिट्टी लेने के लिए प्रोत्साहित करें।

**1.2:** क्या पौधा जड़ द्वारा भूमि से जल एवं खनिज प्राप्त करता है?

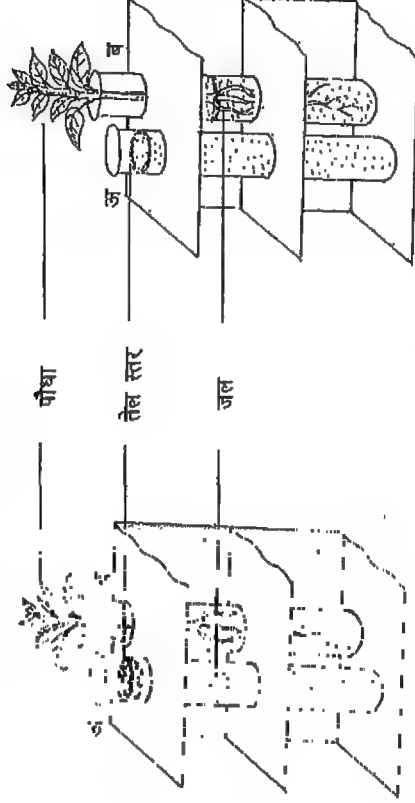
केंद्रित करें: जड़ों द्वारा भूमि से जल एवं खनिज का अवशोषण

(कालांश 1-2)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| | क्रियाकलाप 1<br>छात्रों से कहिए कि दो परखनलियाँ 'अ' तथा 'ब' लेकर स्टैण्ड में लगाये। | |

इस तथ्य से अवगत कराना कि पौधे जड़ों की सहायता से भूमि से जल एवं खनिज का अवशोषण करते हैं

परखनली 'ब' में एक छोटा (कम आयु का) पौधा रखिए
और अब दोनों परखनलियों में इतना पानी डालिए कि दोनों में जल स्तर एक-सा हो जाये।
दोनों परखनलियों में सरसों के तेल की कुछ बूँदें डालिए जिससे जल का वाष्पन न होने पाये।
उपकरण को एक दिन के लिए रखा रहने दीजिए।
दोनों परखनलियों में जल के स्तर का निरीक्षण कीजिए
(अच्छे परिणाम प्राप्त करने के लिए उपकरण को धूप में रखिए)।
उनसे पूछिए:
उपकरण को व्यवस्थि करते समय दोनों परखनलियों में जल का स्तर कितना था?
अब तुम दोनों परखनलियों के जल स्तरों में क्या अंतर देखते हो?
परखनली 'ब' में जल स्तर क्यों गिर जाता है?
परखनली 'अ' में जल के स्तर में परिवर्तन क्यों नहीं होता है?
हम परखनलियों में तेल की बूँदें क्यों डालते है?
इस क्रियाकलाप से आप क्या निष्कर्ष निकालते हैं?

दो परखनलियाँ, परखनली स्टैंड, सरसों का तेल, छोटी (कम आयु का) पौधा, जल

यह निष्कर्ष निकालने में उनकी सहायता कीजिए जड़े भूमि से जल को अवशोषित करती हैं।
इस भूमि-जल में विभिन्न पदार्थ (खनिज) घुले रहते हैं।
ये घुले हुए खनिज भी जड़ों द्वारा जल के साथ अवशोषित कर लिये जाते हैं।

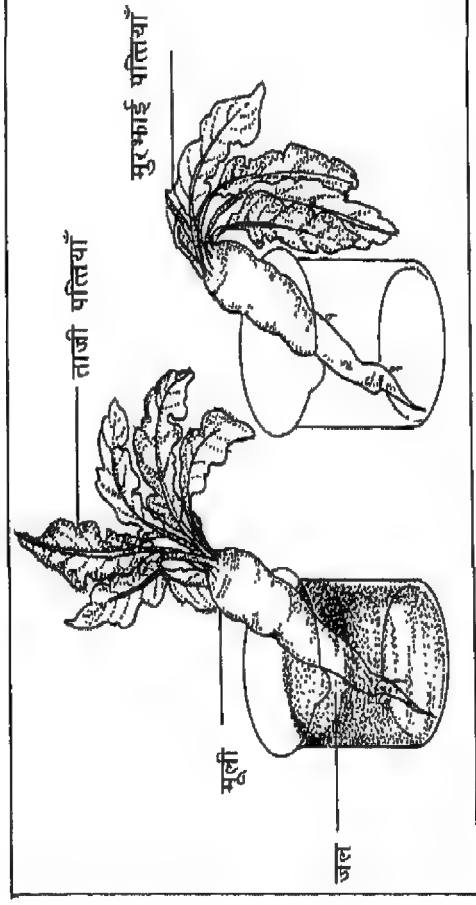
### विस्तारण 1

छात्रों से कहिए कि एक गमले में लगे स्वस्थ पौधे को लें और प्रतिदिन पानी देकर और फिर पानी न देकर दशा का निरीक्षण करें।

गमले में लगा स्वस्थ पौधा

### विस्तारण 2

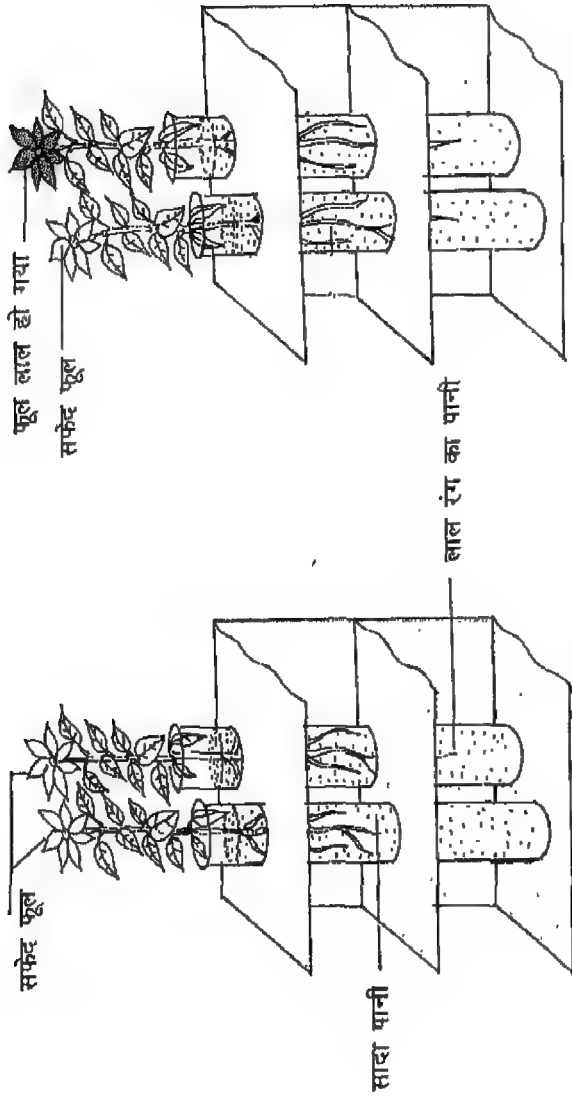
दो मूली/गाजर/खरपतवार के पौधे लीजिए। इनमें से एक को पानी भरे बीकर में रखिए।
दूसरे को हवा में लटका कर या बिना पानी वाले बीकर में रखिए।
कुछ घंटों के बाद दोनों पौधों का निरीक्षण कीजिए।
दोनों पौधों की स्थिति में आप क्या अंतर देखते हो?
पौधे का कौन-सा भाग पानी के सम्पर्क में है?
परिणाम की आपस में विवेचना कीजिए।

दो मूली/गाजर/खरपतवार, पानी, दो बीकर

बिना जल के ताजी पत्तियाँ मुरझा जाती हैं

## 1.3: क्या जड़ द्वारा अवशोषित जल पौधे के विभिन्न भागों में संवाहित होता है?

**केंद्रित करें: जड़ों से पौधे के अन्य भागों तक पानी का संवहन**

(कालांश 1-2)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
| --- | --- | --- |
| इस तथ्य से अवगत कराना कि अवशोषित जल पौधे के अन्य भागों में तने द्वारा संवाहित होता है | क्रियाकलाप 1<br>छात्रों से कहिए कि दो परखनलियाँ अ और ब लेकर स्टैंड में व्यवस्थित करें।<br>परखनली (अ) में थोड़ा जल और परखनली (ब) में लाल रंग का पानी (लाल रोशनाई घोल कर) डालिए।<br>दोनों परखनलियों (अ एवं ब) में जड़-सहित गुलमेंहदी, पिट्यूनियाँ या सफेद फूलों वारे सदाबहार के एक-एक पौधे को रखिए।<br>उपकरण को 3-4 घंटे के लिए इसी प्रकार रखा रहने दीजिए (अच्छे परिणाम के लिए उपकरण को एक दिन के लिए रखिए)<br>छात्रों से कहिए कि वे तना, पत्तियों एवं फूलों में रंग परिवर्तन का निरीक्षण करें।<br>दोनों पौधों की जड़ एवं तने के अनुप्रस्थ-काट काटकर हैन्ड लैन्स की सहायता से अवलोकन कर अंतर मालूम कीजिए।<br>उनसे कहिए कि दोनों पौधों में पाये जाने वाले अंतर का निरीक्षण करें।<br>पौधे के उन भागों का नाम बताइए जो जल को पत्तियाँ एवं फूलों तक पहुँचाने में सहायक होता है।<br><br>दोनों पौधों की जड़ एवं तने के अनुप्रस्थ काट कर तुम क्या अंतर देखते हो?<br>यह निष्कर्ष निकालने में उनकी सहायता कीजिए कि जड़ द्वारा अवशोषित जल, पौधे के अन्य भागों में संवाहित होता है। | दो परखनलियाँ, परखनली-स्टैंड, लाल रोशनाई, गुलमेंहदी/पिट्यूनिया सफेद फूलों वाले सदाबहार के दो जड़-सहित पौधे, कैंची, हैन्ड लैन्स |

दिन भर के लिए लाल रंग के पानी में रखने पर लाल हो जाता है

**विस्तारण 1**

छात्रों को इस प्रकार के क्रियाकलाप करने के लिए प्रोत्साहित कीजिए कि गुलमेंहदी/कमल/लिलि/सफेद फूल तथा लम्बी शाखा वाले सदाबहार के तने को दो अनुलम्ब भागों में काटकर (या चीर कर) एक भाग को नीले जल वाली परखनली में तथा दूसरे भाग को लाल जल वाली परखनली में रखें।

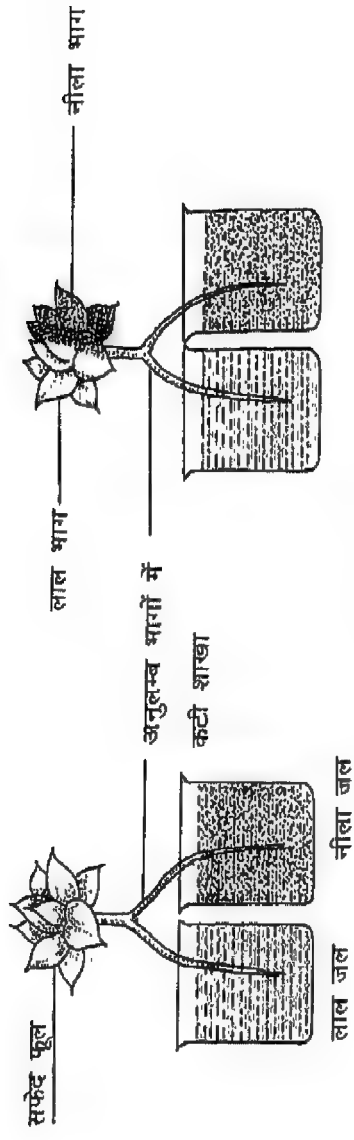
गुल मेंहदी/सदाबहार/लिली या कमल का पौधा, चाकू, लाल और नीला रंग

दो तीन घंटे बाद छात्रों से निरीक्षण के लिए कहिए।

अब निम्न प्रश्नों की विवेचना कीजिए।

फूल का कौन-सा भाग लाल और कौन-सा भाग नीला हो जाता है?

तने के कौन से भाग ने रंगीन पानी को पुष्प तक पहुँचाने में सहायता की है?

(जड़ों में अपनी सतह से एवं मूल रोम द्वारा जल अवशोषण की क्षमता होती है)।

सफेद फूल सहित अनुलम्ब भागों में कटी शाखाएँ, दिन भर के लिए लाल तथा नीले जल में रखने पर, आंशिक लाल तथा आंशिक नीला हो जाते है

**विस्तारण 2**

इसी प्रकार का प्रयोग कैण्डीटफ्ट (सफेद चाँदनी) या पिट्यनिया के दो जड़-सहित पौधों को लेकर कीजिए। एक पौधे को रंगीन पानी भरे जार या बड़ी में रखिए और दूसरे को सादे पानी से भरे जार में। दो-तीन घंटे बाद दोनों पौधों की जड़ एवं तने के अनुप्रस्थ-काट काटकर अंतर का निरीक्षण हैन्ड लैन्स द्वारा कीजिए।

कैन्डीटफ्ट या पिट्यूनिया के दो पौधे, लाल एवं नीली रोशनाई, हैन्ड लैन्स, ब्लेड, बोतल/जार

**1.4:** हरी पत्तियाँ पौधे के लिये भोजन कैसे बनाती हैं?

केंद्रित करें: खाद्य निर्माण के लिए हरे वर्णक (क्लोरोफिल) का महत्व

(कालांश 2-3)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| इस तथ्य को समझना कि हरी पत्तियाँ पौधों के लिए भोजन बनाती हैं | क्रियाकलाप 1<br>छात्रों से चर्चा कीजिए ।<br>उनसे पूछिए:<br>हम एवं अन्य जन्तु अपना भोजन कहाँ से प्राप्त करते हैं?<br>(पेड़-पौधों एवं जानवरों से)<br>पौधे अपना भोजन कैसे प्राप्त करते हैं?<br>(भूमि, सूर्य, वायु तथा पानी आदि से)<br>पत्तियों में सबसे अधिक पाया जाने वाला रंग कौन-सा है?<br>(हरा)<br>छात्रों को बताइए कि पत्तियों का यह हरा रंग एक प्रकार के वर्णक (क्लोरोफिल या पर्ण हरित) के कारण होता है ।<br>उन्हें समझाइए कि सजीव वस्तुओं में पौधे ही ऐसे हैं जो अपना भोजन, पर्णहरित, पानी, कार्बन डाइआक्साइड एवं सूर्य के प्रकाश जैसे बह्य साधनों की सहायता से स्वंय बना लेते हैं ।<br>पौधों द्वारा निर्मित भोजन कहाँ जाता है?<br>हम पौधों से भोजन किस प्रकार प्राप्त करते हैं?<br>छात्रों को स्पष्ट कीजिए कि पौधों द्वारा बनाया अतिरिक्त भोजन पौधे के विभिन्न भागों में एकत्र कर लिया जाता है, जिसको हम लोग अपने खाने में उपयोग करते हैं । पौधे जो खाद्य पदार्थ बनाते हैं वह "शक्कर" या "स्टार्च" के रूप में होता है ।<br><br>क्रियाकलाप 2<br>छात्रों से चर्चा कीजिए कि हरी पत्तियाँ तथा पौधे के अन्य हरे भाग अपना भोजन स्वयं बना सकते हैं । | |

क्रियाकलाप 3

पौधों के जिन भागों का हम भोजन के रूप में उपयोग करते हैं, उन भागों को पहचानना

पौधों के विभिन्न खाए जाने वाले भाग जैसे अदरक, मूली, आलू, फूलगोभी, पालक, केला आदि कक्षा में लाइए और उन्हें दिखाइए ।

अदरक, मूली, आलू, फूलगोभी, चना, पालक तथा केला या कोई और फल

उनसे पूछिए:
पौधों के इन भागों में क्या संग्रहित है?
छात्रों का ध्यान इस तथ्य की ओर आकर्षित कीजिए कि इन भागों में पौधों का अतिरिक्त खाद्य पदार्थ संग्रहित है, जिसे हम खाते हैं ।
उन पौधों के नाम बताइए, जिसकी जड़ें भोजन के रूप में उपयोग की जाती हैं ।
(मूली और गाजर)
उन पौधों के नाम बताइए जिनके तने भोजन के रूप में उपयोग होते हैं?
(अदरक, आलू)
उन पौधों के नाम बताइए जिनकी पत्तियाँ भोजन के रूप में उपयोग होती हैं ।
(पालक एवं पत्ता गोभी)
उन पौधों के नाम बताइए जिनके फूल भोजन के रूप में उपयोग होते हैं ।
(फूल गोभी)
कुछ पौधों के नाम बताइए जिनके फलों एवं बीजों का भोजन के रूप में उपयोग होता है?
(आम, चना)
छात्रों को सारणी भरने में सहायता कीजिए ।

| पौधे का नाम | भोजन के रूप में पौधे के खाए जाने वाले भाग | | | | |
|---|---|---|---|---|---|
| | जड़ | तना | पत्ती | फूल | फल/बीज |
| मूली | ✓ | × | ✓ | × | ✓ |

विस्तारण 1

परीक्षण करिए कि पत्तियों द्वारा बनाया गया भोजन मंड (स्टार्च) के रूप में होता है । एक कटोरी में आलू के कुछ टुकड़े लीजिए और उसमें कुछ बूँदें आयोडीन घोल की डालिए । आलू के स्टार्च को गहरे नीले रंग

आलू, आयोडीन घोल, गेहूँ का आटा, कटोरी

में परवर्तित कर देता है । (आयोडीन का घोल, टिन्चर आयोडीन ले कर उसमें थोड़ा पानी मिला कर बनाया जा सकता है) इसी प्रकार का परीक्षण गेहूँ के आटे के साथ किया जा सकता है ।

### विस्तारण 2

डेसीमीटर घनाकार बर्तन, कीप, परखनली, जलीय पौधा, कटोरी

छात्रों एक प्रयोग व्यवस्थित करने में सहायता कीजिए जिससे उन्हें यह मालूम हो कि हरी पत्तियाँ जब भोजन बनाती हैं तो आक्सीजन गैस निकलती है ।

डेसीमीटर घनाकार बर्तन को 3/4 भाग पानी से भरिए । एक जलीय पौधा लीजिए । (वह पौधा जो जल के अंदर उगता है जैसे हाईड्रिला, सेरेटोफिलम) इस पौधे को चित्र के अनुसार पानी से भरे डेसीमीटर घनाकार बर्तन में उल्टी कीप के अंदर रखिए । अब पानी से पूरी भरी एक परखनली लीजिए । उसके मुँह में अपना अंगूठा लगाकर उल्टाकर कीप के निकास सिरे के ऊपर रखिए ।



पत्तियों द्वारा भोजन बनाने की प्रक्रिया में आक्सीजन गैस बुलबुले के रूप में

सम्पूर्ण उपकरण को सूर्य की रोशनी में लगभग एक घंटा रखिए और पौधे से निकलते हुए बुलबुलों की ओर छात्रों का ध्यान दिलाइए ।
उनसे पूछिए:
बुलबुले क्यों निकलते है?
समझाइए कि हरी पत्तियों द्वारा भोजन बनाने की प्रक्रिया में आक्सीजन गैस बुलबुलों के रूप में निकलती है ।

**1.5:** क्या फूलों से फल और बीज उत्पन्न होते हैं?
केंद्रित करें: अधिकांश फूल, फल एवं बीज उत्पन्न करते हैं ।

(कालांश-1)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| | क्रियाकलाप1 | |
| फूलों से फल एवं बीज उत्पन्न होते हैं, इसकी जानकारी देना | (चूँकि इस क्रियाकलाप में लम्बे समय तक नियमित निरीक्षण करना पड़ेगा अतः छात्रों से कहिए कि वे मौसम के पुष्पीय पौधों का 2-3 सप्ताह तक निरीक्षण करें) ।<br>फूल से फल में परिवर्तन होने का उनको निरीक्षण करने दीजिए ।<br>फल को खोलिए या काटिए । उसके अंदर के भागों का उन्हें निरीक्षण करने दीजिए ।<br>फल को खोलिए या काटिए । उसके अंदर के भागों का उन्हें निरीक्षण करने दीजिए ।<br>मौसम के फल जैसे मटर, चना, सेव आदि को भी कक्षा में खोलकर देखा जा सकता है ।<br>यह निष्कर्ष निकालने में उनकी सहायता कीजिए कि फूलों से फल तथा बीज उत्पन्न होते हैं । | मौसम के फल, फूल एवं बीज |
| | **विस्तारण 1**<br>छात्रों से कहिए कि आस-पास से विभिन्न प्रकार के फलों एवं बीजों को एकत्र करें ।<br>उनसे कहिए कि वे स्क्रेप बुक में किसी पौधे का चित्र बनाकर विभिन्न रंगों के बीजों अथवा दालों से उस चित्र को भरें । | बीज, गोंद, स्क्रेप बुक |
| | **विस्तारण 2**<br>छात्रों से कहिए कि वे सूखे फूलों का हरबेरियम तैयार करें वे दबाए गए सूखे बधाई पत्र भी बना सकते हैं । | फूल एवं स्क्रेप बुक |

**1.6:** क्या बीजों से नए पौधे उगते होते हैं?
कोंद्रित करें: बीजों से नए पौधे उत्पन्न होते हैं ।

(कालांश 2-3)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| जानना कि बीजों से नए पौधे उगते हैं | क्रियाकलाप 1<br>छात्रों से कहिए कि वे सेम, और कुछ काले व सफेद चने के बीजों को पानी में भिगोएँ।<br>उन्हें बताइए कि भिगोने से बीज मुलायम हो जाते हैं, और इस प्रकार उनकी आंतरिक रचना आसानी से देखी जा सकती है ।<br>छात्रों से कहिए कि भीगे हुए बीजों के छिलके निकालकर तथा हैन्डलैंस की सहायता से निरीक्षण करें ।<br>उनसे पूछिए:<br>तुम क्या देखते हो?<br>यह निष्कर्ष निकालने में उनकी सहायता कीजिए कि दिखाई देने वाला यह भाग "तरूण" पौधा है, और वह प्रक्रम जिसके द्वारा यह बाहर आता है, अंकुरण कहलाता है । | सोख्ता कागज, बीज (सरसों, सेम, चना, मूँग), पानी, हैन्डलैंस प्लास्टिक थैलो |

सारणी भरने में उनकी सहायता कीजिए ।

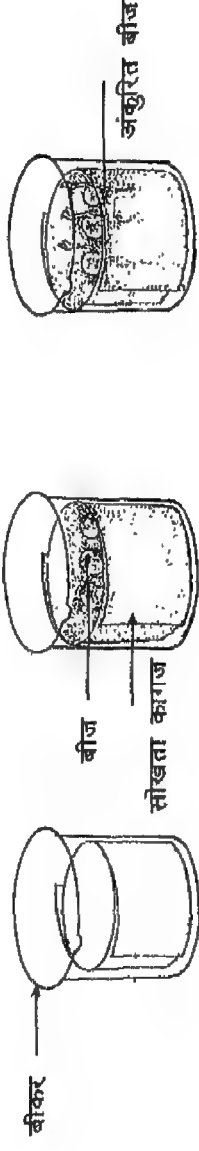
लक्षण

| बीज के प्रकार | बड़ा | छोटा | मुलायम | कठोर | छिलके उतरने वाले | छिलके न उतरने वाले |
|---|---|---|---|---|---|---|
| शुष्क बीज | | | | | | |
| भिगोए हुए बीज | | | | | | |

क्रियाकलाप 2

छात्रों से कहिए कि एक बीकर में थोड़ा सा पानी लें। सोख्ता कागज को गोलाई में घुमाकर अंदर पानी में रखें। बीकर के बीच में गोली रूई रखें।

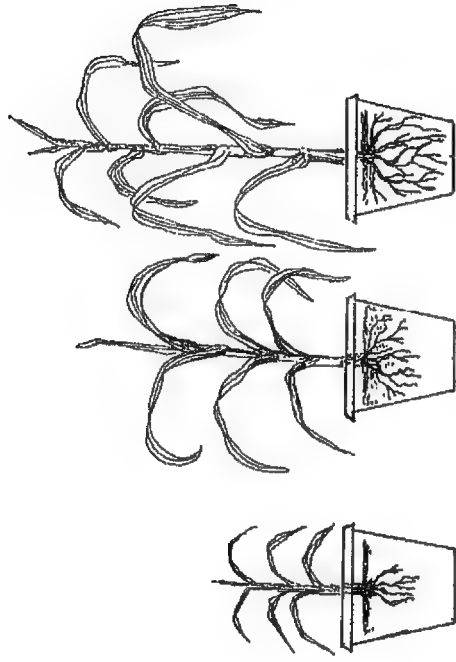
बीकर, सोख्ता कागज, रूई बीज, पानी

कागज और बीकर के मध्य उन स्वस्थ बीजों को रखिए जिनके अंकुरण पर प्रयोग करना चाहते हो।
सोख्ता कागज द्वारा सोखा हुआ पानी बीजों को प्राप्त हो जाएगा।
सोख्ता के स्थान पर रूई या अखबारी कागज भी ले सकते हैं।
कुछ दिनों बाद बीज अंकुरित होने लगेंगे।
छात्रों से कहिए कि बीजों में होने वाले परिवर्तनों का प्रति दिन निरीक्षण करें।

अंकुरण के लिए बीज कहाँ से पानी पाते हैं?
बीज से सर्व प्रथम कौन-सा भाग बाहर निकलता है?
यह किस दिशा में वृद्धि करता है?
इसके पश्चात् कौन-सा भाग निकलता है?
पौधे के जो भाग क्रमशः अंकुरण के समय बीजों से निकलते हैं उन्हें बताइए।

विस्तारण 1

मिट्टी का एक बर्तन (दिया) या प्लास्टिक की प्लेट लेकर इसमें कुछ मिट्टी डालिए और विभिन्न प्रकार के बीजों को अंकुरित कराइए।

मिट्टी का बर्तन (दिया) प्लास्टिक की प्लेट मिट्टी, बीज

बीजों में वृद्धि की विभिन्न अवस्थाओं के चित्र बनाने के लिए कहिए।

पौधों की वृद्धि

**1.7:** क्या बीजों का प्रकीर्णन विभिन्न प्रकार से होता है?
केंद्रित करें: उन संरचनाओं पर जो बीजों के प्रकीर्णन में सहायक होती है।

(कालांश 2-3)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| बीजों एवं फलों की रचना तथा उनके लक्षणों का ज्ञान कराना, जो उनके प्रकीर्णन में सहायक होते हैं | क्रियाकलाप 1<br>एक चार्ट बनाइए तथा विभिन्न प्रकार के कुछ बीजों का संग्रह कराइए जो वायु द्वारा, जल द्वारा कपड़ो अथवा जन्तुओं के शरीर में लग कर प्रकीर्णन करते हैं। छात्रों को चार्ट तथा नमूने दिखाइए और उनसे परिचर्चा कीजिए।<br>उनसे पूछिए:<br>फल खाने के बाद उनके बीजों का तुम क्या करते हो?<br>गर्मियों में हवा में उड़ते हुए दिखाई देने वाले कुछ बीजों के साथ रोमयुक्त संरचनाएँ क्या होती हैं? | अंकुश, शूल, कंटक, कड़े बाल आदि संरचनाओं वाले विभिन्न प्रकार के बीजों को प्रदर्शित करने वाला चार्ट |

तुम्हारे या किसी अन्य जन्तु, के बाग या मैदान में भ्रमण करते समय शरीर/कपड़ों पर चिपकी काटों वाली संरचना क्या होती है?

तुम उन बीजों एवं फलों को क्या करते हो जो तुम्हारे कपड़ों में चिपक जाते हैं?

कोई अन्य संरचना बताइए जो बीजों एवं फलों के हवा में उड़ने में सहायक होती है?

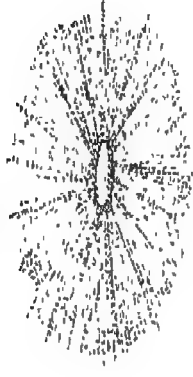
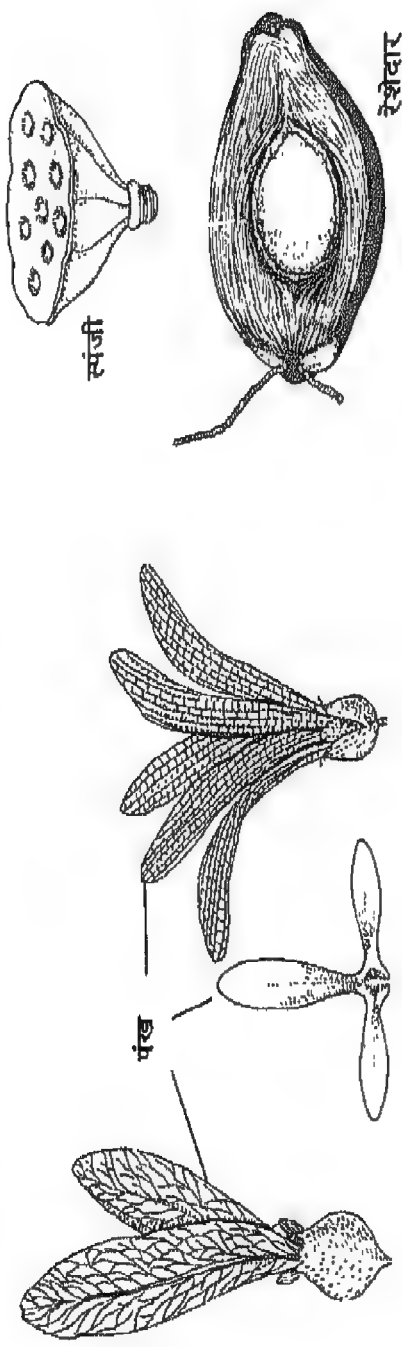
(रोम और पंख)

कमल और नारियल जैसे पौधे कहाँ उगते हैं?

कमल और नारियल के फलों का प्रकीर्णन किस प्रकार होता है?

(रेशेदार एवं स्पंजी संरचना)

मटर, सेम, गुलमेंहदी तथा अरण्ड के बीजों का प्रकीर्णन किस प्रकार होता है?

(फलों के स्फुटन द्वारा)

यह निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि ये बीजों की संरचनाएँ उनके मातृ पौधे से दूर प्रकीर्णन में सहायक होती हैं ।

विभिन्न प्रकार के बीजों/फलों की संरचनाऐं प्रकीर्णन में सहायक होती है

विस्तारण 1

बीजों के विभिन्न प्रकीर्णन साधनों की सारणी बनाइए (हवा, जल जन्तु, एवं मनुष्य) ।

| पौधों का नाम | प्रकीर्णन का माध्यम | संरचना | संरचना का चित्र |
|---|---|---|---|
| कपास | हवा | रोम | |
| कमल | | | |
| लटजीरा | | | |
| आम | | | |
| मटर | | | |

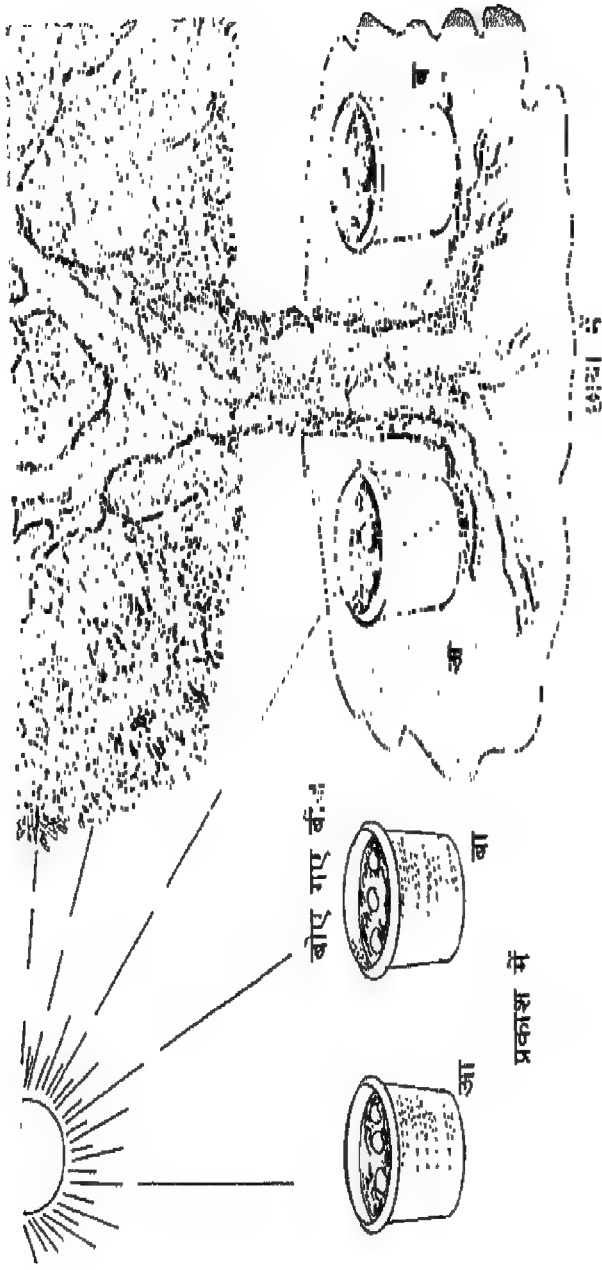
**विस्तारण 2**

अपने पड़ोस के स्थान में छात्रों को ले जाकर विभिन्न प्रकार के बीजों एवं फलों का अवलोकण कर एकत्रित करने को कहिए, जिनमें रोम, पंख, कांटे एवं अंकुश आदि हों।

**1.8:** मातृ पौधे से बीजों एवं फलों का प्रकीर्णन क्यों होना चाहिए?

केंद्रित करें: बीजों एवं फलों का प्रकीर्णन स्वस्थ पीढ़ियों के सातत्य के लिए आवश्यक है।

(कालांश

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सा |
|---|---|---|
| सामान्यीकरण करना कि बीजों एवं फलों का प्रकीर्णन नए पौधे की पृद्धि एवं उनके गुणन के लिए आवश्यक है | क्रियाकलाप 1<br>विचार विमर्श द्वारा छात्रों से निम्नलिखित उदाहरण देकर प्रश्न पूछिए —<br>यदि आपकी कक्षा में छात्रों की संख्या दुगनी हो जाए तो क्या आतको बैठने के लिए पर्याप्त स्थान मिल सकेगा?<br>यदि पाँच छात्रों के पास खाने कें लिए पाँच केले हैं और आपके पास पाँच अन्य छात्र खाने के लिए आ जाते हैं तो क्या आपको पूरा केला खाने को मिलेगा?<br>छात्रों को कहिए कि वे एक समान चार पौलीथिन की थैली या गमले लें।<br>सभी में कुछ बगीचे की मिट्टी डालें फिर गमलों को केवल अ, आ, ब, बा, चिन्हित करें।<br>अब गेहूँ/चना के दो-चार बीजों को 'अ' 'आ', चिन्हित गमलों में बोइए।<br>उसी प्रकार के 10-20 बीजों को 'ब' 'बा' चिन्हित गमलों में बोइए।<br>अ, ब गमलों को पेड़ की छाया में तथा आ, बा, को प्रकाश में रखिए।<br>टिप्पणी: अन्य सभी परिस्थितियाँ पानी तथा खाद्य पदार्थ की आपूर्ति सभी में समान होनी चाहिए।<br>छात्रों से कहिए कि 5-6 दिन के बाद निरीक्षण करें।<br>उनसे पूछिए:<br>किस गमले में अंकुरित बीजों से स्वस्थ पौधों का विकास हुआ है?<br>विशेषकर और गमलों में सभी बीजों के अंकुरण से स्वस्थ पौधों का विकास क्यों नहीं हुआः?<br>सभी गमलों के पौधों की वृद्धि का निरीक्षण कर अंतर का पता लगाएं।<br>उपर्युक्त क्रियाकलाप से आप क्या निष्कर्ष निकालते हैं? | बर्तन, पौलीथीन थैले, बीज, मृदा, जल |

निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि पौधों मे पास-पास होने से उनमें स्वस्थ वृद्धि नहीं होती। अतः मातृ पौधों से फलों एवं बीजों का प्रकीर्णन आवश्यक है, अन्यथा वृद्धि के लिए पर्याप्त स्थान, सूर्य का प्रकाश एवं भोजन नहीं प्राप्त होगा।

**विस्तारण 1**

खेतों में जाइए अथवा माली से पूछिए कि बीजों को बोते समय उनके बीच में पर्याप्त स्थान क्यों छोड़ते हैं?

**1.9: क्या पौधे हमारे लिए उपयोगी हैं?**

केंद्रित करें: पौधों की मनुष्य के लिए उपयोगिता ।

(कालांश 2-3)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
| --- | --- | --- |
| पौधों की हमारे जीवन में उपयोगिता को अवगत कराना । | क्रियाकलाप 1<br>छात्रों को उनके पूर्व ज्ञान का, निम्नलिखित प्रश्नों द्वारा स्मरण कराइए ।<br>मनुष्य की मूल आवश्यकताएँ क्या हैं?<br>आदि मानव क्या खाते थे?<br>आदि मानव अपने शरीर को ढकने के लिए क्या प्रयोग करते थे?<br>आदि मानव कहाँ रहते थे?<br>प्रतिदिन के मुख्य भोजन में तुम कौन-कौन से खाद्य पदार्थों का प्रयोग करते हो, का नाम बताइए?<br>इन सभी, खाद्य पदार्थों को तुम कहाँ से प्राप्त करते हो?<br>गाय, भैंस, बकरी आदि अपना भोजन कहाँ से प्राप्त करती हैं?<br>मेज, कुर्सी, चाक बोर्ड, चारपाई आदि किस सामग्री की बनी होती हैं?<br>(लकड़ी, इमारती लकड़ी)<br>गावों में भोजन पकाने एवं वस्तुओं को गर्म करने के लिए क्या जलाया जाता है?<br>जब तुम्हें सर्दी जुकाम हो जाता है तो तुम्हारी दादी माँ तुलसी की चाय देना क्यों पंसद करती हैं?<br>(औषधीय उपयोगिता)<br>बहुत से ग्रामीण नीम की दातून से अपने दाँत साफ करता क्यों पंसद करते हैं?<br>उन पौधों के नाम बताइए जिनकी लकड़ी का उपयोग घर बनाने में होता है?<br>(चीड़, साल आदि)<br>पौधों के अपघटित भाग हमारे लिए किस प्रकार उपयोगी हैं?<br>(खाद्य बनाने में)<br>प्रतिवर्ष हम लोग वन-महोत्सव क्यों मनाते है?<br>(अधिक वृक्ष लगाने तथा उनके संरक्षण के लिए) | चार्ट, पौधों की उपयोगिता का प्रदर्शन (अनाज, दालें, रेशे, औषधि प्रदान करने वाले पौधे) |

हमें अपने आस-पास अधिक पौधे क्यों लगाने चाहिए?
यह निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि पौधे हमारे लिए उपयोगी हैं ।

**विस्तारण 1**

छात्रों से कहिए कि उन पौधों के नाम लिखें जो निम्न लिखित सारणी में दर्शाए गए हैं ।

| पौधों के नाम जो प्रदान करते हैं | | | | | |
|---|---|---|---|---|---|
| अनाज | दालें | फल | औषधि | रेशे | तेल |
| | | | | | |
| | | | | | |

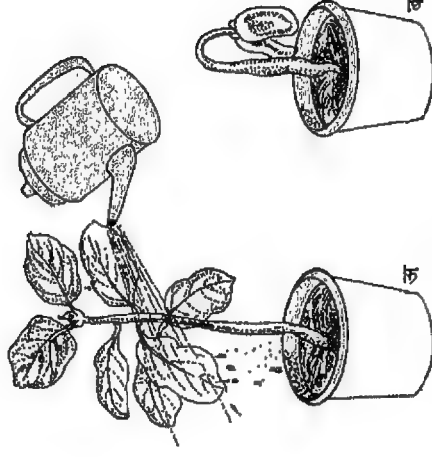
**विस्तारण 2**

छात्रों से कहिए कि वे अनाज, दाल, तेल प्रदान करने वाले बीजों एवं फलों तथा औषधि प्रदान करने वाले पौधों की पत्तियों का एक छोटा संग्रह करें ।

**1.10: क्या पौधों की देखभाल एवं सुरक्षा की आवश्यकता पड़ती है?**
**केंद्रित करें: पौधों की देखभाल एवं सुरक्षा ।**

(कालांश 1-2)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| तथ्य समझना कि पौधों की उचित देखभाल एवं सुरक्षा होनी चाहिए | क्रियाकलाप 1<br>छात्रों को कहिए कि वे दो गमलों में लगे पौधों (कोलियस का पौधा) को लें और उन्हें 'अ', 'ब' से चिन्हित करें ।<br>केवल 'अ' गमले वाले पौधे को पानी एवं खाद दीजिए तथा 'ब' वाले को नहीं ।<br>एक सप्ताह बाद दोनों पौधों का निरीक्षण कीजिए । | दो गमलों में लगे कोलियस के पौधे, खाद, पानी |

उनसे पूछिएः
तुम क्या देखते हो?

पौधे को पानी एवं मृदा में खाद मिलाने से पौधा स्वस्थ होता है

क्रियाकलाप 2

यह जानना कि अत्यधिक गर्मी, ठंड और निरंतर छाया, पौधों की वृद्धि पर प्रभाव डालते हैं

चार गमलों में लगे हुए कोलियस या अन्य पौधे,

चार गमलों में लगे पौधे (कोलियस का पौधा) लेकर 'अ', 'ब', 'स', 'द', द्वारा चिन्हित कीजिए। गमले ''अ'' को सूर्य के प्रकाश (अत्याधिक गर्मी), ''ब'' को छाया में, ''स'' गमले को ठंडक में तथा ''द'' गमले को सामान्य दशा (सामान्य गर्मी, सूर्य का प्रकाश एवं जल) में रखें।

सभीगमलों को एक सप्ताह तक उसी दिशा में रखे रहने दीजिए। तत्पश्चात् पौधों में होने वाले परिवर्तन का निरीक्षण कर नोट कीजिए।

(अत्यधिक गर्मी में रखा पौधा मुरझा जाएगा)

(छाया में रखा पौधा पीला पड़ जाएगा लेकिन इसमें लम्बाई में तीव्र वृद्धि होती है, जिससे यह पतला पड़ जाएगा)।

(ठंड में रखे पौधों की वृद्धि अवरूद्ध हो जाएगी तथा पत्तियाँ विकृत हो जाएँगी)
(सामान्य दशा में पौधा स्वस्थ रहेगा और उसमें सामान्य वृद्धि होगी) ।

क्रियाकलाप 3

छात्रों से परिचर्चा कीजिए और पूछिए:
क्या तुमने किसान/माली को अपनी फसलों एवं पौधों पर डी.डी.टी. एवं गैमक्सीन आदि को छिड़कते देखा है?
किसान अपने खेतों में चिड़ियों एवं जानवरों को भगाने के लिए गुलेल, विभिन्न प्रकार की आवाजें, भ्रामक तथा कंटीले तारों द्वारा घेराबंदी का क्यों प्रयोग करता है?
प्रायः किसान/माली खेतों तथा घास के बगीचों में चलने से क्यों मना करता है?
(पौधों का पैरों से कुचलना उनकी वृद्धि के लिए हानिप्रद है)
खेतों और बगीचों के पौधों को घूमते जानवरों से बचाने के लिए आवश्यक उपाय बताइए ।
इस तथ्य की ओर छात्रों का ध्यान आकर्षित कीजिए कि पौधों को अपनी वृद्धि एवं अस्तित्व बनाए रखने के लिए देखभाल एवं सुरक्षा की आवश्यकता होती है ।

विस्तारण 1

यदि तुम्हारे पास दूरदर्शन रेडियो हो तो "कृषि दर्शन" प्रोग्राम देखिए, सुनिए तथा अपनी कक्षा में चर्चा कीजिए । — दूरदर्शन/रेडियो

विस्तारण 2

लकड़ियों की खप्पचियों और फटे पुराने कपड़ों की सहायता से भ्रामक (धोखा) बनाकर अपने बगीचे या पड़ोस के खेतों में लगाकर देखिए कि क्या यह वास्तव में कौओं को भगाता है । — फटे पुराने कपड़े, खप्पचियाँ

**1.11: क्या जन्तु मनुष्य के लिए उपयोगी हैं?**
**केंद्रित करें: जन्तुओं की मनुष्यों के लिए उपयोगिता ।**

(कालांश 1-2)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| | क्रियाकलाप 1<br>छात्रों से पूछिए कि वे उन जानवरों के नाम बताएँ जो खेत जोतने में सहायक होते हैं? | |

यह पहचानना कि हमारे लिए जन्तु भी पौधों के समान उपयोगी हैं

उन वस्तुओं के नाम बताएँ जो जानवरों के विभिन्न भागों के उपयोग से तैयार होते हैं?
तुम्हारे जूते, बैल्ट, दस्ताने किससे बने हैं?
हम चमड़ा कहाँ से प्राप्त करते हैं?
उन खाद्य पदार्थों के नाम बताइए जो विभिन्न जानवरों से प्राप्त होते हैं?
उन जन्तुओं के नाम बताइए जिनसे अंडे, माँस, तथा दूध प्राप्त होते हैं?
किस जानवर को "रेगिस्तान का जहाज" कहते हैं और क्यों?
उन जानवरों के नाम बताइए जो एक स्थान से दूसरे स्थान तक बोझ ढोने के काम आते हैं?
क्या कभी तुमने ताँगे या हाथी की सवारी की है?
क्या तुमने लकड़ी के लट्ठे ढोते हुए हाथी को और पीठ पर मिट्टी के थैले ढोते हुए गधे को देखा है?
(यदि नहीं, तो आप चित्र प्रदर्शन या चर्चा कर सकते हैं)
विभिन्न जानवरों का मल (गोबर) हम किस उपयोग में लाते हैं?
निष्कर्ष निकालने में सहायता कीजिए कि जन्तु भी मनुष्य के लिए पौधों के समान उपयोगी हैं।

विस्तारण 1

छात्रों से कहिए वे आस-पास मुर्गी पालन/दुग्धशाला का भ्रमण करें।

विस्तारण 2

छात्रों से कहिए कि वे गाँव में भ्रमण कर, गोबर से कंडा बनाते हुए तथा उन्हें दीवार पर सुखाते हुए देखें।

विस्तारण 3

छात्रों को कहिए कि उन जन्तुओं के नाम लिखें जो निम्नलिखित वस्तुएँ अथवा साधन प्रदान करते हैं।

| जन्तुओं के नाम जो प्रदान करते है | | | | |
|---|---|---|---|---|
| भोजन | यातायात | खेती | चमड़ा | ऊन |
| | | | | |

**1.12:** क्या जन्तुओं की भी देखभाल एवं सुरक्षा की आवश्यकता होती है?
केंद्रित करें: जन्तुओं की सुरक्षा एवं देखभाल ।

(कालांश 1-2)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| ज्ञान करना कि जन्तुओं को भी देखभाल एवं सुरक्षा की आवश्यकता होती है । | क्रियाकलाप 1<br>वन्य जीवन पर छात्रों से चर्चा कीजिए ।<br>उनसे पूछिए:<br>वन्य जीवों की सुरक्षा के लिए वन किस प्रकार सहायक होते हैं?<br>(जन्तुओं को छिपने एवं भोजन प्रदान करने में)<br>किसी एक वन्य जन्तु का नाम बतलाइए जो जंगलों की लम्बी-लम्बी घासों में छिपकर, अपने शिकार के ऊपर कूदकर उनको मार डालता है और खा जाता है?<br>(चीता, हिरण को पकड़ने के लिए)<br>कुछ जन्तुओं के नाम बताइए जो घास पत्ती आदि खाते हैं?<br>यदि पेड़ पौध/घास आदि नष्ट कर दिए जाएँ तो सभी जन्तुओं का क्या होगा?<br>शासन ने जंगली जन्तुओं का शिकार करने तथा उनके मारने पर प्रतिबन्ध क्यों लगा रखा है? | |
| पहचानना कि प्राकृतिक संतुलन बनाए रखने के लिए पेड़-पौधों की सुरक्षा एवं देखभाल आवश्यक है | क्रियाकलाप 2<br>साधन एवं सामग्री में बताए गए चार्ट को बनाकर छात्रों को दिखाइए<br>उनसे पूछिए<br>तुम किस प्रकार की कालोनी में रहना पसंद करोगे और क्यों?<br>पेड़-पौधे पर्यावरण की सुरक्षा में हमारे लिए किस प्रकार सहायक हैं? छात्रों का ध्यान इस तथ्य की ओर आकर्षित करें कि पौधे प्रकाश संश्लेषण की क्रिया द्वारा वायुमण्डल की दूषित वायु कार्बन डाई आक्साइड का उपयोग कर आक्सीजन गैस निकालते है, जो वायु प्रदूषण दूर करने में सहायक होती हैं । पौधे जल-चक्र की प्रक्रिया में भी सहायक होते हैं, जिससे वर्षा होती है । छात्रों को बोध कराइए कि पेड़ पौधे एवं जन्तुओं की सुरक्षा एव देखभाल आवश्यक है क्योंकि वे हमारे लिए कई तरह से उपयोगी हैं तथा प्राकृतिक संतुलन बनाएँ रखने में सहायक हैं । | सुन्दर पार्क/मैदान युक्त कालोनी को प्रदर्शित करने वाला चार्ट<br><br>पौधों रहित वहुमंजिले भवनों का चार्ट |

पेड़-पौधों रहित बहुमंजिले भवन

पार्क युक्त आवास कालोनी

विस्तारण 1

राष्ट्रीय उद्यान वनस्थल एवं अजायबघर आदि दिखलाने के लिए शैक्षिक भ्रमण की व्यवस्था कीजिए।

विस्तारण 2

छात्रों को कहिए कि अपने पालतू जानवरों की सुरक्षा एवं देखभाल पर एक छोटा-सा निबन्ध लिखकर अपनी कक्षा में पढ़ें।

विस्तारण 3

छात्रों से कहिए कि जल-जीवशाला (एक्वेरियम) बनायें।
(अनुभाग 3 ख 1 देखें)

## इकाई 2: मानव शरीर, पोषण तथा स्वास्थ्य

(हमारा शरीर तथा इसके कार्य; भोजन और उसकी स्वच्छता, सुरक्षित जल, स्वच्छता एवं बीमारियां)

प्रस्तावना

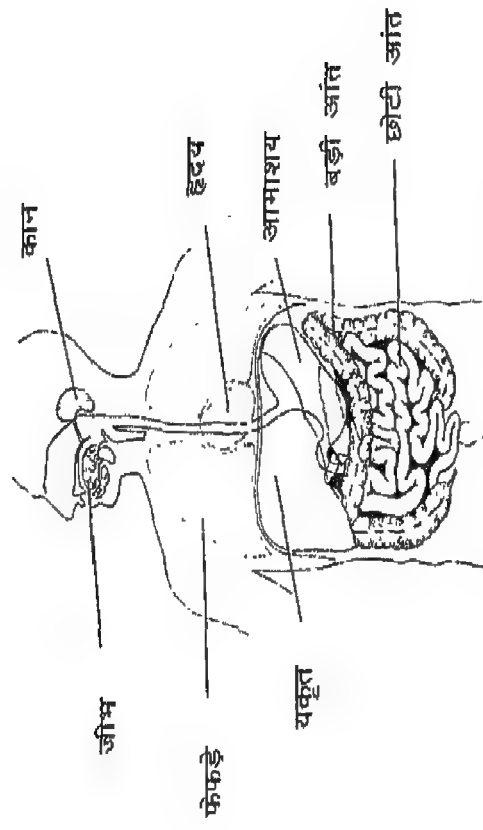
छात्र कक्षा 3 में मानव शरीर के प्रमुख बाह्य अंगों का अध्ययन कर चुकें हैं। वे विभिन्न प्रकार के भोजन पदार्थों से भी परिचित हैं। व्यक्तिगत स्वास्थ्य विज्ञान संबंधी अपेक्षित आदतों के बारे में भी जानते हैं।

इस इकाई द्वारा छात्रः

- मानव शरीर के आन्तरिक अंगों जैसे फेफड़े, हृदय, आमाशय, यकृत की पहचान करने तथा उनके कार्य के बारे में जानने,
- विभिन्न भोज्य पदार्थों का वर्गीकरण करने तथा अच्छे स्वास्थ्य के रख रखाव से संबंधित जानकारी प्राप्त करने,
- पाचन तंत्र के विभिन्न भागों की पहचान करने में तथा पाचन क्रिया का साधारण ज्ञान प्राप्त करने,
- खाद्य पदार्थों तथा इसके पोषक तत्वों के परिरक्षण एवं संरक्षण के लिए संग्रहण, पकाने और परोसने के लिए अपनाएँ जाने वाले विभिन्न तरीकों को समझने,
- भोजन किस प्रकार संदूषित हो जाता है और इसे कैसे रोका जा सकता है, इसको समझने,
- प्रदूषित जल को पहचानने में तथा इसे शोधन द्वारा पीने के योग्य बनाने,
- अस्वास्थ्यकर परिस्थितियाँ, मक्खियों और मच्छरों के जनन के लिये जगह बनाती हैं तथा इन्हें स्वास्थ्यकर कैसे बनाया जा सक्ता है, को पहचानने, में समर्थ होंगे।

**2.1:** मानव शरीर के आंतरिक अंग क्या हैं और वे किस प्रकार कार्य करते हैं?
केंद्रित करें: विभिन्न आंतरिक अंग और उनके कार्य

(कालांश 4)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| मानव शरीर के आन्तरिक अंगों की पहचान करना | क्रियाकलाप 1<br>मानव शरीर के प्रमुख आन्तरिक अंगों का चार्ट दिखाई।<br>मानव शरीर के अन्दर विभिन्न अंग कौन-कौन से हैं।<br>(फेफड़े, हृदय, आमाशय, यकृत, आंत, वगैरह)<br>उन्हें बताइए कि फेफड़े हृदय, यकृत तथा आमाशय हमारे शरीर के महत्वपूर्ण आन्तरिक अंग हैं!<br>छात्रों से कहिए कि वे मानव शरीर के आन्तरिक अंगों की सूची बनाएँ। | मानव शरीर के आंतरिक अंगों का चार्ट |

मानव शरीर के प्रमुख आन्तरिक अंग

क्रियाकलाप 2

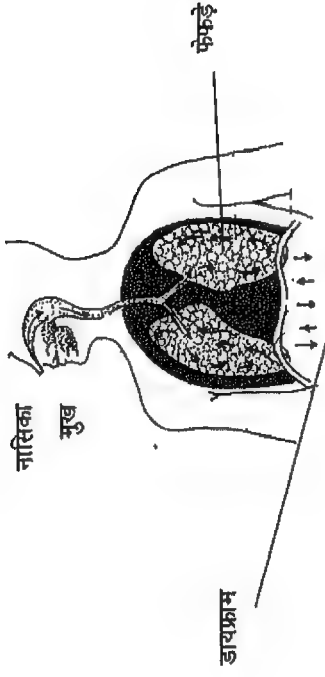
छात्रों से कहिए कि वे अपने मुख तथा नासिका को कुछ समय के लिए बंद करें।

पूछिएः

तुम क्या महसूस करते हो?

छात्रों को बोध कराइए कि जब उनके मुख तथा नासिका बन्द होते है तब वे श्वास नहीं ले सकते।

पूछिएः

जब उनकी नासिका खुली होती है तब उससे किस चीज़ का आवागमन होता है? (वायु)

मानव शरीर में श्वसन मार्ग

क्रियाकलाप 3

यह देखना कि क्रिया में वक्ष का क्रमशः प्रसार तथा संकुचन होता है

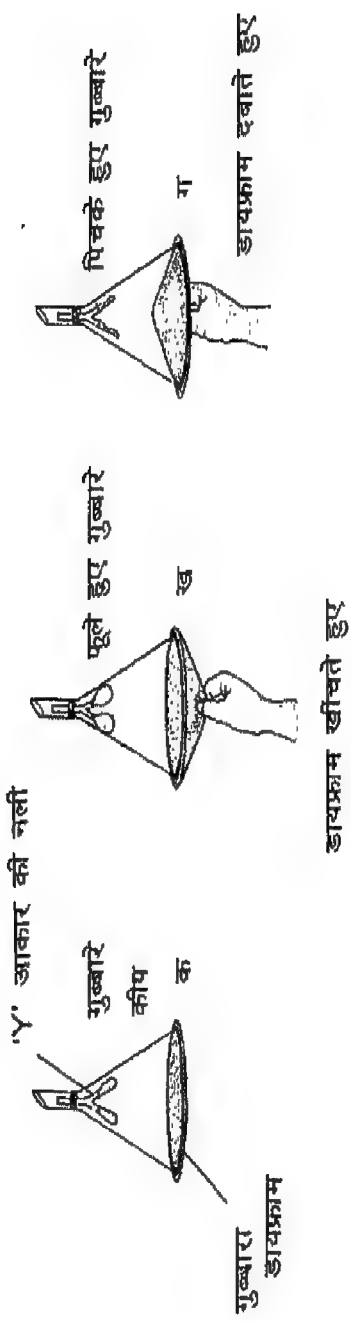
छात्रों से कहिए कि जब वे श्वास लेते हैं तथा छोड़ते हैं तब एक दूसरे का वक्ष फीते की सहायता से नापें। (मापने वाले फीता)

परिचर्चा कीजिए:
दोनों नापों में क्या अन्तर है?
इस अन्तर के क्या कारण हैं?
छात्रों को बोध कराइए कि निश्वसन क्रिया में वक्ष का प्रसार होता है और निःश्वसन क्रिया में क्रिया में वृक्ष संकुचित होता है।

क्रियाकलाप 4

फेफड़ों के कार्यों को पहचानना

(कीप, दो छोटे गुब्बारे, 'Y' नलिका, एक बड़ा गुब्बारा, ब्लेड, धागा)

पूछिए:
छात्रों से श्वसन क्रिया पर परिचर्चा कीजिए।
हम श्वास कैसे लेते हैं?
दिए गए चित्र के अनुसार प्रयोग तैयार कीजिए। एक कीप, 'Y' आकार की नलिका दो छोटे गुब्बारे तथा एक बड़ा गुब्बारा लीजिए। दो छोटे गुब्बारे 'Y' नलिका की दो छोटी भुजाओं में लगाइए और लम्बी तथा सीधी भुजा को कीप में चित्र के अनुसार लगाइए।
इसके बाद एक बड़ा गुब्बारा लेकर उसे आधा काट कर कीप के मुंह पर लगाइए।

श्वसन क्रिया

कटे हुए गुब्बारे की रबर मनुष्य के डायफ्राम की तरह कार्य करती है (स्थिति "क") ।
एक छात्र से कहिए कि डायफ्राम को नीचे की ओर खींचे (स्थिति "ख") और फिर डायफ्राम को ऊपर की ओर दबाएं (स्थिति "ग") ।

पूछिएः
स्थिति "ख" में गुब्बारों की स्थिति कैसी है?
स्थिति "ग" में गुब्बारों की स्थिति कैसी है?
कीप के अन्दर गुब्बारों की स्थिति क्या होती है जब डायाफ्रम में गति होती है?

छात्रों को बोध कराइए कि इसी प्रकार वक्षीय ढांचे के प्रसार से वायु नासिका, श्वास नली से होकर फेफड़ों में प्रवेश करती है (स्थिति "ख") । जब वक्षीय ढांचा संकुचित होता है (स्थिति "ग") तब उसी मार्ग द्वारा कार्बन डाईआक्साइड युक्त वायु फेफड़े से बाहर निकलती है ।

पूछिएः
क्या हम मुख द्वारा श्वास ले सकते हैं?

छात्रों को समझाइए कि मुख द्वारा भी सांस ली जा सकती है परन्तु ऐसा करना हानिप्रद है । वायु जब नासिका से होकर गुजरती है तो उसमें पायी जाने वाली धूल तथा हानिकारक जीवाणु नासिका मार्ग में उपस्थित रोयों के द्वारा छन जाते हैं । साथ ही यह जाड़ों में गर्म और गर्मी में ठण्डी हो जाती है, जब कि मुख द्वारा ऐसा नहीं हो पाता । मुख द्वारा श्वास लेने से ठंडक पकड़ने या संक्रमण की सम्भावना रहती है ।

प्रातः काल गहरी सांस लेने से स्वच्छ वायु अधिक मात्रा में फेफड़ों में प्रवेश करती है, जो अच्छे स्वास्थ्य के लिए लाभप्रद होती है।

पूछिए:
जो वायु निश्वसन में ली जाती है और जो वायु निःश्वसन में निकलती है, उसमें क्या अन्तर है? (निश्वसित वायु में आक्सीजन की मात्रा निःश्वसित वायु की अपेक्षा अधिक होती है, तथा निःश्वसित वायु में कार्बनडाईआक्साइड की मात्रा निश्वसित वायु की अपेक्षा अधिक होती है)

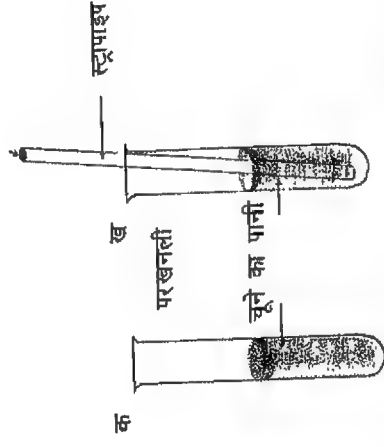
क्रियाकलाप 5

यह पहचानना कि निःश्वसित वायु में निश्वसित वायु की अपेक्षा कार्बन-डाईआक्साइड की मात्रा अधिक होती है

(चूने के पानी के निर्माण की विधिः बिना बुझे चुने का एक टुकड़ा लीजिए। इस टुकड़े को बीकर/हांडी में रख कर पानी से भर दीजिए। पानी गर्म हो जाता है तथा अन्त में दूधिया हो जाता है। कुछ (2-3) घंटों तक इसे छोड़ दीजिए। चूना तलछट के रूप में बैठ जाएगा और ऊपर का साफ पानी, चूने का पानी होगा)।

पानी, बीकर, बिना बुझा चूना, स्ट्रापाइप

चित्र के अनुसार प्रयोग सेट कीजिए। दो परखनली लेकर उनके चौथाई भाग को चूने के पानी से भर दीजिए। परखनली "अ" को आधे घंटे के लिए अलग रख दें।

दो परखनलीयां, कांच की नली/स्ट्रापाइप, चूने का पानी



वायु (कार्बन डाई आक्साइड) फूंकने से चूने का पानी दूधिया हो जाता है

किसी छात्र से परखनली "ख" में स्ट्रापाइप द्वारा मुंह लगा कर वायु फूंकने को कहिए ।
पूछिएः -
जब तुम नलिका/स्ट्रापाइप द्वारा परखनली "ख" में वायु फूंकते हो तो क्या देखते हो?
क्या टेस्ट ट्यूब "क" के चूने के पानी में कोई परिवर्तन देखते हो?
छात्रों का ध्यान इस तथ्य की ओर आकृष्ट कीजिए कि स्वच्छ वायु में कार्बन डाईआक्साइड की मात्रा बहुत कम होती है जो चूने के पानी को दूधिया करने के लिए अपर्याप्त है अतः चूने का पानी स्वच्छ बना रहता है । जब हम वायु को चूने के पानी में फूंकते हैं तो वह दूधिया हो जाता है क्यों कि इसमें कार्बनडाईआक्साइड की मात्रा अधिक होती है ।

क्रियाकलाप 6

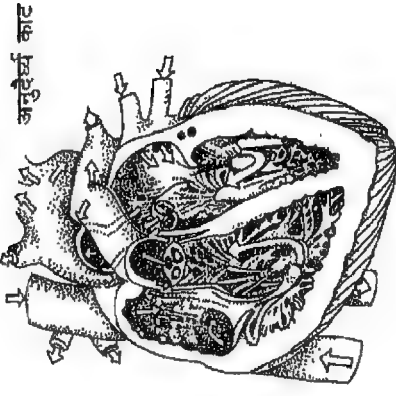
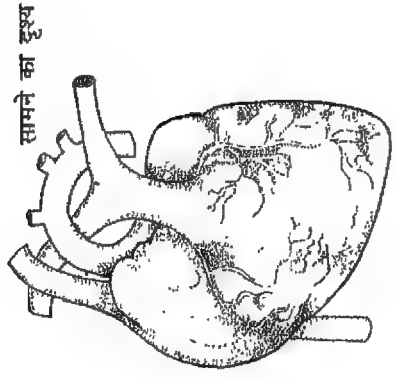
यह देखना कि दौड़ने, व्यायाम करने, तथा शारीरिक श्रम करने में श्वास लेने की दर बढ़ जाती है

छात्रों को तीन वर्गों क, ख, ग, में बाँट दीजिए । वर्ग "क" के छात्रों से कहिए कि पांच मिनट तक मैदान में दौड़ें । वर्ग "ख" के छात्रों से कहिए कि पांच मिनट तक व्यायाम करें । वर्ग "ग" के छात्रों को कक्षा में बैठे रहने दीजिए । एक छात्र से कहिए कि वह तीनों वर्गों के छात्रों के श्वसन गति का निरीक्षण करें ।
परिचर्चा कीजिएः
तीनों वर्गों के छात्रों में श्वास लेने में क्या अन्तर है?
इगिंत कीजिए कि दौड़ने से, व्यायाम करने से अथवा शारीरिक श्रम करने से श्वसन की दर बढ़ जाती है ।

क्रियाकलाप 7

मानव-हृदय के कार्य को पहचानना

हृदय का चार्ट

छात्रों से कहिए कि वे अपना हाथ वक्ष के ऊपर रखें और अनुभव करने का प्रयास करें । फिर कुछ छात्रों से कहिए कि वे अपने साथी के वक्ष पर कान रखें और सुनने का प्रयास करें ।
निरीक्षण के आधार पर परिचर्चा कीजिएः
तुम क्या अनुभव करते हो?
कौन से अंग में धड़कन हो रही है? (हृदय, हृदय के धड़कने को हृदय गति कहते हैं) ।
तुम वक्ष के किस ओर हृदय की धड़कन स्पष्ट अनुभव करते हो?
छात्रों को चार्ट की सहायता से समझाइए कि मानव शरीर के वक्ष में मध्य से थोड़ा बांयी ओर एक अत्यन्त महत्वपूर्ण अंग स्थित है । यह एक प्रकार का है जो रक्त को शरीर के विभिन्न अंगों में पहुंचाता है (हृदय) । जिस ध्वनि का अनुभव तुम करते हो वह इसी अंग की गति के कारण है ।

मानव हृदय

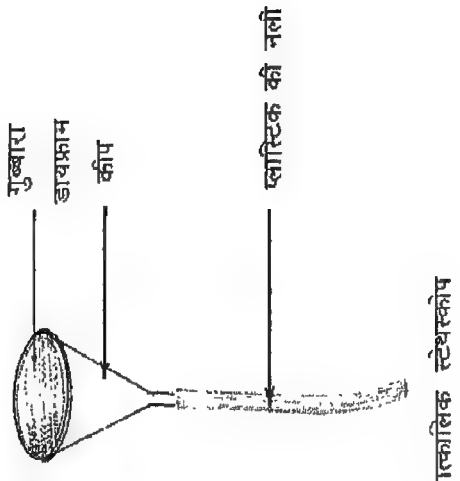
यह देखना कि दौड़ने, व्यायाम तथा कठिन शारीरिक श्रम करने से हृदय गति (धड़कन) पर प्रभाव पड़ता है

क्रियाकलाप 8

कीप, रबर की नली, गुब्बारा,

क्रियाकलाप 2.1.6 को दुबारा कराइए और छात्रों से कहिए कि तात्कालिक स्टेथस्कोप की सहायता से सभी वर्गों के छात्रों की हृदय गति का अनुभव करें तथा तुलना करें।
नीचे दिए गए चित्र के अनुसार इसे निर्मित कर सकते हैं।

पूछिए:
क्या तीनों वर्गों के छात्रों की हृदय गति में तुम कोई अन्तर अनुभव कर रहे हो?
किस वर्ग के छात्रों में हृदय गति अधिक तेज है?
किस वर्ग के छात्रों में हृदय गति धीमी है?
छात्रों को समझाइए कि विश्राम की स्थिति की तुलना में दौड़ने, व्यायाम करने या कठिन शारीरिक परिश्रम करने से हृदय गति तेज हो जाती है।

तात्कालिक स्टेथस्कोप

श्वसन दर तथा हृदय गति में परस्पर सह-सम्बन्ध पहचानना

क्रियाकलाप 9

पूछिए:

तुम क्या अनुभव करते हो जब तुम दौड़ कर लौटते हो?

छात्रों को इस बात का बोध कराइएं कि कठिन श्रम (दौड़ना, व्यायाम तथा शारीरिक श्रम आदि), श्वसन दर तथा हृदय गति दोनों को तेज कर देता है ।

**2.2: हम अच्छे स्वास्थ्य के रख रखाव (अनुरक्षण) का विविध भोज्य पदार्थो से संबंध कैसे स्थापित कर सकते हैं?**

**केंद्रित करें: भोज्य पदार्थों के विभिन्न वर्ग तथा अच्छा स्वास्थ्य**

(कालांश 1-2)

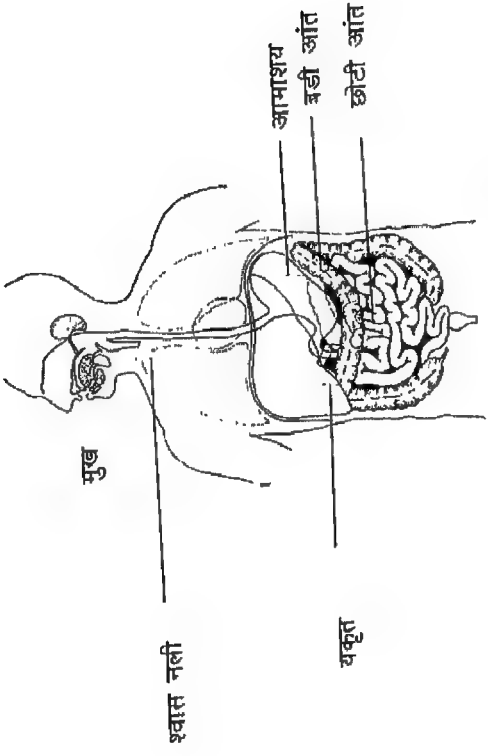
| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| भोज्य पदार्थों को विभिन्न वर्गों, ऊर्जा प्रदान करने वाले, शरीर का निर्माण करने वाले तथा संरक्षात्मक, में वर्गीकृत करना | क्रियाकलाप 1<br>नीचे दी गयी सारणी को श्यामपट्ट पर बना कर उसमें प्रतिदिन के भोजन में प्रयुक्त सामग्रियों को छात्रों से पूछ कर लिखें । उन्हें पिछली कक्षा के ज्ञान को पुनः स्मरण कराइए और उनसे कहिए कि प्रत्येक भोज्य सामग्री के सामने भोजन का वर्ग अ, ब, स के रूप में अंकित करें ।<br>अ – ऊर्जा प्रदान करने वाले भोज्य पदार्थ (शर्कर तथा वसा)<br>ब – शरीर का निर्माण करने वाले भोज्य पदार्थ (प्रोटीन)<br>स – संरक्षात्मक भोज्य पदार्थ (विटामिन तथा खनिज लवण) | |

| भोज्य पदार्थ | भोजन वर्ग | | |
|---|---|---|---|
| | अ | ब | स |
| चावल | ✓ | ✗ | ✗ |
| दूध | ✓ | ✓ | ✓ |
| अण्डा | ✓ | ✓ | ✓ |
| आलू | ✓ | ✗ | ✗ |
| दालें | ✗ | ✓ | ✗ |
| हरी सब्जियाँ | ✗ | ✗ | ✓ |
| फल (आम) | ✓ | ✗ | ✓ |
| घी | ✓ | ✗ | ✗ |
| अंकुरित बीज (अनाज) | ✓ | ✗ | ✓ |
| किण्वित भोजन | ✓ | ✗ | ✗ |

| | | |
|---|---|---|
| | छात्रों के साथ विचार विमर्श करके स्पष्ट कीजिए कि तीनों वर्गों के भोज्य पदार्थ जो स्थानीय परिवेश में उपलब्ध हों तथा सामर्थ्य के अन्दर हों उन्हें अपने प्रतिदिन के भोजन में अवश्य लेना चाहिए। इस प्रकार का भोजन मनुष्य को शारीरिक रूप से पुष्ट, बलवान तथा रोग-मुक्त एवं रोग-निरोधक बनाता है। | |
| उचित स्वास्थ्य के अनुरक्षण के लिए विभिन्न भोज्य वर्गों के महत्व को पहचानना | क्रियाकलाप 2<br>छात्रों से कहिए कि दाल, चपाती, चावल आदि भोज्य पदार्थों की एक सारणी बनाए, जिसमें प्रतिदिन प्रातः कालीन कलेवा, दोपहर के भोजन, सांय कालीन कलेवा तथा रात्रि के भोजन में लिए गए भोज्य पदार्थों को विभिन्न वर्गों में प्रदर्शित करें।<br>परिचर्चा कीजिएः<br>तुम्हारे प्रतिदिन के भोजन में कौन-सा वर्ग सम्मिलित नहीं है?<br>यदि कोई एक वर्ग तुम्हारे भोजन में नहीं है तो उसका तुम्हारे स्वास्थ्य पर क्या प्रभाव पड़ेगा?<br>टिप्पणीः अच्छे स्थानीय भोज्य पदार्थों को खाने की आदत को प्रोत्साहित कीजिए। | |

**2.3: मानव शरीर के अन्दर पाचन के लिये भोजन कहाँ जाता है?**
केंद्रित करेंः पाचन तंत्र

(कालांश 2-3)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| पाचन तंत्र के विभिन्न अंगों को पहचानना | क्रियाकलाप 1<br>छात्रों को चार्ट की सहायता से समझाइए कि भोजन, निगलने के बाद क्रमशः ग्रासनली, आमाशय, छोटी आंत और बडी आंत से होकर जाता है। उन्हें यह भी समझाइए कि यकृत तथा अग्नाशय, महत्वपूर्ण पाचन ग्रन्थियां हैं जो पाचन तंत्र के अभिन्न अंग हैं।<br>पूछिएः<br>ठोस भोजन खाते समय आप अपने दांतों से क्या करते हैं?<br>छात्रों को बोध कराइए कि जो भोजन हम खाते है वह छोटे-छोटे टुकड़ों में टूट जाता है। ऐसा दांतों द्वारा चबाने तथा पीसने से होता है। | मानव के पाचन-तंत्र का चार्ट |

मानव के पाचन-तंत्र का रेखा चित्र

भोजन चबाने तथा निगलने के पश्चात् हमारे शरीर में कहाँ जाता है?
उन अंगों के नाम बताओ जहाँ होकर भोजन निगलने के बाद से लेकर शरीर के बाहर निकलने तक गुजरता है?
परिचर्चा कीजिए तथा पाचन-तंत्र के चार्ट में दिए गए विभिन्न अंगों को पहचानने में छात्रों की सहायता कीजिए।

उन अंगों तथा उनके कार्यों की पहचान करना, जिनसे चबाया हुआ भोजन शरीर में जाता है

क्रियाकलाप 2

डबलरोटी/चपाती

डबलरोटी/चपाती के कुछ टुकड़े छात्रों को देकर उनसे कहिए कि कुछ समय तक अच्छी तरह चबाएँ।
पूछिएः
अब रोटी का स्वाद कैसा है?
तुम चबाने के पहले तथा बाद में क्या अन्तर अनुभव करते हैं?
छात्रों को यह अनुमान लगाने में मदद कीजिए कि भली प्रकार रोटी चबाने पर मीठी लगती है। लार रोटी

| | | |
|---|---|---|
| | के साथ मिलती है। लार में पाचक रस (इन्जाइम) होता है जो भोजन या रोटी की मंड (स्टार्च) को शर्करा के रूप में सरलीकृत कर देता है।<br>इसी प्रकार आहार-नाल के अन्य भागों जैसे आमाशय तथा छोटी आंत में पाचक रस भोजन से मिलते हैं, और अघुलनशील भोजन को सरल तथा घुलनशील भोजन में बदल देते हैं। यह सरल तथा घुलनशील भोजन आंतों द्वारा अवशोषित कर लिया जाता है और शरीर में ऊर्जा, वृद्धि तथा बीमारियों से सुरक्षा प्रदान करने में सहायक होता है। | |
| | चार्ट की सहायता से स्पष्ट कीजिए कि पचा हुआ सरल एवं घुलनशील भोजन छोटी आंतों की दीवारों में रक्त द्वारा अवशोषित कर लिया जाता है जो शरीर द्वारा ऊर्जा, वृद्धि तथा बीमारियों से सुरक्षा प्रदान करने के लिये प्रयुक्त होता है। बचा हुआ शेष भोजन रूक्षांश और मल होता है जो बड़ी आंत से होकर शरीर के बाहर निकल जाता है।<br>छात्रों को बोध कराइए कि दोपहर तथा रात्रि के भोजन के पश्चात् पिया गया पानी भोजन के पाचन में सहायक होता है। इसलिए प्रतिदिन प्रर्याप्त मात्रा में पानी पीना चाहिए क्योंकि यह पाचन के लिए तथा अच्छे स्वास्थ्य के अनुरक्षण के लिए लाभदायक होता है। | मानव के पाचन तंत्र का चार्ट |

## 2.4: भोजन तथा उसके पोषक तत्वों को नष्ट होने से बचाने के लिए क्या सावधानियाँ बरतनी चाहिए?

केंद्रित करें: भोजन का परिरक्षण तथा संरक्षण

(कालांश 2-3)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| | क्रियाकलाप 1 | |
| भोजन के भंडारण, पकाने तथा परोसने के उचित तरीकों को पहचानना। | छात्रों से कहिए कि वे एक रोटी का टुकड़ा या कुछ पका हुआ चावल खुले तथा नम स्थान में और एक रोटी का टुकड़ा या कुछ पका हुआ चावल शुष्क, हवादार तथा ढकी हुई जगह में रखें।<br>दो दिन उपरान्त छात्रों से कहिए कि इन स्थानों में रखे भोज्य पदार्थों का आंखों से और फिर आवर्धक लेन्स की सहायता से निरीक्षण करें। | चपाती अथवा पका हुआ चावल, आवर्धक लेंस |

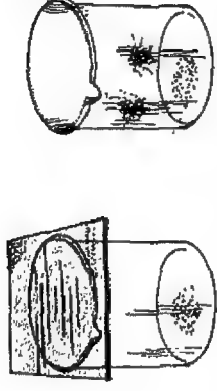
पूछिएः
दोनों परिस्थितियों में रखे भोज्य पदार्थों में तुम क्या अंतर देखते हो?
(नम तथा खुले स्थान में रखे भोजन पर एक पतली सफेद, भूरी अथवा काली फंफूदी की पर्त जम जाती है) ।
क्या इसमें कोई गंध है?
छात्रों को बोध कराइए कि पके भोजन को खुली तथा नम जगह में रखने पर वह खराब हो जाता है जबकि भोज्य पदार्थों को ढक कर हवादार तथा शुष्क स्थानों में रखने पर वे जल्दी खराब नहीं होते हैं ।

क्रियाकलाप 2

छात्रों से विचार विनिमय के आधार पर उनका ध्यान इस और आकृष्ट कीजिए कि भोजन परोसते समय यह ध्यान रहे कि आवश्यकता से अधिक भोजन न परोसा जाए, जिससे बिना खाए भोजन को फेंकना पड़े । भोजन सावधानी से परोसा जाए जिससे कि छलक कर अथवा बिखर कर नष्ट न हो जाए ।
उन्हें यह बताइए कि आवश्यकता से अधिक पकाने से विटामिन तथा अन्य पोषक तत्व नष्ट हो जाते हैं । इसलिए इस स्थिति से बचना चाहिए ।
विटामिन तथा लवण पानी में घुलनशील होते हैं इसलिए शेष पानी को फिर से प्रयोग कर लेना चाहिए ।

**2.5: भोजन किस प्रकार संदूषित होता है और इसे संदूषण से कैसे बचाया जा सकता है?**
**केंद्रित करेंः संदूषण के परिपेक्ष्य में भोजन संबंधी अच्छी आदतें ।**

(कालांश 2)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| यह समझना कि भोजन कैसे संदूषित होता है | क्रियाकलाप 1<br>चौड़े मुँह वाली दो बोतल/कटोरी/बीकर और एक ढक्कन लीजिए ।<br>दोनों में गुड़ के छोटे-छोटे टुकड़े या शक्कर के दाने रखकर उनमें से एक को ढक्कन से ढक दीजिए और दूसरे को खुला छोड़ दीजिए । एक घंटे के बाद छात्रों से कहिए कि उनका निरीक्षण करें । | बीकर/चौड़े मुंह वाली बोतल/कटोरी, मिठाई, गुड़ या चीनी (5 ग्राम), धातु की चादर (ढक्कन) |

बिना ढ़के भोजन से मक्खियां आकर्षित होती हैं

पूछिएः
तुम क्या देखते हो?
तुम किस बोतल में रखी चीनी/गुड़ को खाना चाहोगे और क्यों?
खुली बोतल की चीनी/गुड़ क्यों हानिकारण है?
ये मक्खियाँ कहां से आती है?

छात्रों से विचार विनिमय कीजिए कि मक्खियाँ भोजन तक रोगाणुओं को पहुंचाने में माध्यम का कार्य करती है। खुली बोतर में रखी चीनी/गुड़ पर धूल जम जाती है, जिसके द्वारा रोगाणु भोजन तक पहुँच जाते हैं। इस प्रकार खुले स्थान पर रखे भोजन को ग्रहण करने से अतिसार, हैजा या पेचिस हो सकता है।

निष्कर्ष निकालने के लिए प्रोत्साहित कीजिए कि भोजन हमेशा ढक कर तथा संदूषण से सुरक्षित रखना चाहिए। खुलाहुआ बाजार का भोजन (मिठाइयाँ, चाट, आदि) भी संदूषित हो जाते हैं, इसलिए उसे कभी भी नहीं खाना चाहिए।

क्रियाकलाप 2

यह समझना कि संदूषण से कैसे बच जा सकता है

स्वच्छता संबंधी निर्देशों का चार्ट

अपने द्वारा बनाये चार्ट की सहायता से दर्शाइए कि गंदे हाथों चम्मचों अथवा पात्रों द्वारा भोजन संदूषित होता है। अतः निम्न बिन्दुओं पर ध्यान दीजिएः

(1) भोजन सदैव स्वच्छ पात्रों में ढककर रखना चाहिए तथा स्वच्छ हाथों से या स्वच्छ चम्मचों द्वारा निकालना चाहिए।
(2) भोजन करने के पूर्व हमें अपने हाथ साबुन तथा पानी से अच्छी तरह धोने चाहिए।
(3) नियमित रूप से नाखून काटने एवं साफ करने चाहिए।

(4) संदूषण से बचाने के लिए प्रयोग में न आने वाले भोजन को रेफ्रिजरेटर (फ्रिज या अभिनवीकृत/तात्कालिक फ्रिज) में रखना चाहिए। रोगाणु सामान्य एवं गर्म जगह में तेजी से वृद्धि करते हैं।

(5) दाल, दूध आदि को उबालकर खराब होने से बचाया जा सकता है।

**विस्तारण 1**

छात्रों से कहिए कि वे घर पर इस बात का निरीक्षण करें कि दाल या दूध गर्मियों के मौसम में कुछ ही घंटों में खराब हो जाते हैं।

**2.6: जल किस प्रकार प्रदूषित हो जाता है?**

**केंद्रित करें: जल प्रदूषण के स्रोत।**

*(कालांश 2-3)*

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| यह पहचानना कि जल कैसे प्रदूषित होता है | क्रियाकलाप 1<br>परिचर्चा कीजिए:<br>पानी के विभिन्न स्रोत क्या हैं?<br>विद्यालय तथा घर में हम पेय जल कहां से प्राप्त करते हैं? | दो गिलास/बीकर, पानी, मिट्टी |
| | क्रियाकलाप 2<br>दो गिलास/बीकर लीजिए। एक गिलास/बीकर में स्वच्छ जल तथा दूसरे गिलास/बीकर में गन्दा पानी लीजिए।<br>पूछिए:<br>तुम किस गिलास/बीकर का पानी पीना पसन्द करोगे? क्यों?<br>अन्य क्या विधियाँ हैं जिनसे जल प्रदूषित हो सकता है?<br>चार्ट की सहायता से छात्रों द्वारा निष्कर्ष निकलवाइए कि पानी के स्रोत के पास कपड़े धोने, बर्तन साफ करने, मनुष्य तथा जानवरों के स्नान करने आदि कारणों से जल प्रदूषित होता है। | जल-प्रदूषण का चार्ट |

जल प्रदूषण

जल प्रदूषण और भी कई कारणों से होता है जैसे जब नालियों का गन्दा पानी, कल कारखानों का गन्दा पानी, पशुओं तथा मानवों का मलमूत्र, पेय जल के सम्पर्क में आ जाता है ।
तुम तालाबों या अन्य असुरक्षित स्त्रोतों से पानी क्यों नहीं पीते हो?
निम्नलिखित पर बल देने के लिए चर्चा कीजिए:

(1) छात्रों को रुका हुआ पानी पीने के लिए हतोत्साहित कीजिए जैसे तालाब और झील से
(2) बिना जगत वाले तथा बिना छायेदार कुओं का पानी पीने के लिए प्रयोग नहीं करना चाहिए ।
(3) घरों तथा विद्यालय में पीने का पानी साफ बर्तनों में संग्रह करना चाहिए । इन बर्तनों को साफ करके पानी प्रतिदिन बदल देना चाहिए ।
(4) पानी निकालते समय हाथों को बर्तन में नहीं डुबाना चाहिए ।

**विस्तारण 1**

**वातावरण में पानी के स्त्रोतों के प्रदूषण के तरीकों का निरीक्षण करें ।**

क्रियाकलाप 3

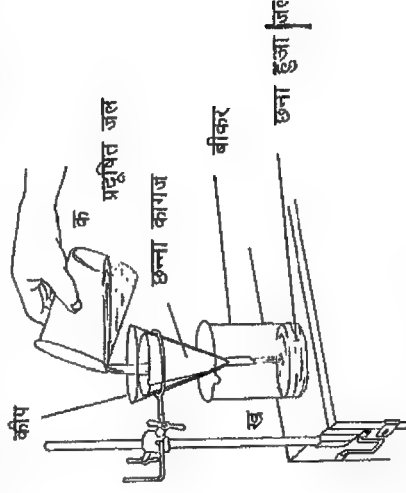
प्रदूषित पानी को पीने योग्य शुद्ध करने की विधियों की जानकारी करना (उबालकर, छान कर तथा रसायनों की सहायता से)

दो बीकर, तालाब का पानी, मिट्टी के तेल का बर्नर, कीप, छन्ना कागज

तालाब के कुछ पानी को एक बीकर 'क' में उबालिए, फिर इसे ठंडा होने के लिए रख दीजिए । छात्रों द्वारा निरीक्षण करवाइए ।

पूछिएः

तुम बीकर की तली में क्या देखते हो?

छात्रों को दिखाइए कि जो पदार्थ बीकर के तल पर बैठ गये है वे अशुद्धियाँ हैं, जिन्हें निथारकर अलग किया जा सकता है । पानी को उबालने से इसके जीवाणु नष्ट हो जाते हैं । यह पानी के शुद्धीकरण की उत्तम विधि है ।

छान कर प्रदूषित जल को शुद्ध करना

तालाब के कुछ पानी को एक दूसरे बीकर 'ख' में छन्ना कागज की सहायता से छानिए । छात्रों से कहिए कि पानी तथा छन्ना कागज का निरीक्षण करें ।

पूछिएः

बीकर "क" तथा बीकर "ख" के पानी में तुम क्या अन्तर देखते हो?

तुम छन्ना कागज के ऊपर क्या देखते हो?

यह निष्कर्ष निकालने के लिए छात्रों को प्रोत्साहित कीजिए कि तालाब के पानी की गन्दगी छानने की क्रिया से दूर की जाती है । महीन मलमल का कपड़ा भी छानने के लिए प्रयोग किया जा सकता है ।

क्रियाकलाप 4

तालाब के पानी को एक बीकर में लीजिए । उसमें कुछ फिटकरी मिलाकर हिलाइए और कुछ समय के लिए मेज पर रख दीजिए । छात्रों से कहिए कि निरीक्षण करें ।

बीकर, तालाब का पानी, फिटकरी

पूछिएः

तुम क्या देखते हो?

यह निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि कुछ रसायनों को पानी में मिलाने से गन्दगी दूर की जा सकती है और पानी पीने योग्य बनाया जा सकता है । कुएँ के पानी को पोटेशियम परमेंगनेट (लाल दवा) या ब्लीचिंग पाउडर मिला कर शुद्ध किया जा सकता है ।

शहरों तथा कस्बों में पीने का पानी टंकियों तथा ऊंची टंकियों में संग्रह किया जाता है । इस पानी को क्लोरीनीकरण के पश्चात् को उपलब्ध कराया जाता है । पोटेशियम परमेंगनेट तथा क्लोरीन हानिप्रद जीवनणुओं को समाप्त कर देते हैं तथा पानी को पीने योग्य बनाते हैं ।

विस्तारण 1

छात्रों से कहिए कि वे शुद्ध किए गए पानी के महत्व पर विज्ञापन बनाएं तथा नारे तैयार करें ।

विस्तारण 2

यदि समीप में नल लगा हो तो उसे बूंद-बूंद करके टपकने दीजिए और रात के बाद सुबह देखिए कि कितना पानी बाल्टी में एकत्र हो गया है । छात्रों को प्रभावित कीजिए कि टपकते नलों को यदि सुधारा न जाए तो कितना पानी बेकार बह जाएगा ।

**2.7: आस पास की स्वच्छता अनेक बीमारियों की रोकथाम में कैसे सहायक होती है?**

**केंद्रित करें: अस्वास्थ्यकर स्थितियों में रहने से हानियां**

(कालांश 2-3)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| उन कारणों की पहचान करना जो आस-पास को अस्वास्थ्यकर बनाते है | क्रियाकलाप 1<br>परिचर्चा कीजिएः<br>आस-पास को अस्वास्थ्यकर बनाने वाले कारण क्या हैं?<br>छात्रों को एक ऐसी जगह ले जाइए जो स्वच्छ व साफ हो और फिर दूसरी जगह ले जाइए जहां कूड़ा करकट फेंका हुआ हो या ढेर लगा हो।<br>पूछिएः<br>दोनों स्थानों में क्या अन्तर है?<br>छात्रों का ध्यान इस ओर आकर्षित कीजिए कि स्नान, करने, कपड़े धोने, कूड़ा फेंकने, थूकने, पेशाब करने तथा मल विसर्जन, आदि को उचित स्थान पर न करने से पास-पड़ोस अस्वास्थ्यकर बनता है। | |
| यह जानना कि आस-पास की अस्वास्थ्यकर स्थितियाँ, मक्खी और मच्छर, जो रोगाणुओं के वाहक हैं, के जन्म का कारण हैं | क्रियाकलाप 2<br>छात्रों को ऐसे स्थान पर भी ले जाइए जहां नाला बन्द या रुका हुआ हो।<br>पूछिएः<br>तुम क्या देखते हो?<br>यह दिखाकर बताइए कि आस-पास की ऐसी अस्वास्थ्यकर स्थितियां मक्खियों तथा मच्छरों के प्रजनन के लिए उपयुक्त है। वे मलेरिया तथा हैजा आदि को फैलाने वाले रोगाणुओं को लाती हैं। | |
| उन तरीकों का पहचानना जिनसे मक्खियों तथा मच्छरों के जनन की रोकथाम की जा सके | क्रियाकलाप 3<br>चर्चा कीजिएः<br>मक्खियों तथा मच्छरों के प्रजनन को रोक सकने के क्या तरीके हैं?<br>पास-पड़ोस को स्वच्छ रखने के महत्व को छात्रों को बताइए तथा यह भी बताइए कि मच्छर तथा मक्खी के प्रजनन को चूना और डी.डी.टी. आदि बिखेर कर रोका जा सकता है। | |

नालियों को ढ़की रखने और उन्हें घरेलू बगीचे में ले जाने से गन्दा पानी एकत्र नहीं हो पाता है, जिससे मच्छर, मक्खी पैदा नहीं हो पाते हैं ।

तालाब तथा गड्ढ़े में एकत्र पानी के ऊपर मिट्टी के तेल का छिड़काव करना चाहिए । इस छिड़काव से पानी के ऊपर तेल की एक पतली पर्त बन जाती है जो मच्छरों के लार्वों को मारकर उनके प्रजनन को रोकती है । प्रोत्साहित कीजिए कि गन्दे तथा अस्वच्छ शोचालय मक्खियों के शीघ्र जनन में सहायक होते हैं इसलिए इन्हें शौच के बाद पानी से, हो सके तो फिनाइल से, भली प्रकार साफ रखना चाहिए ।

## इकाई 3: पदार्थ और उनके गुण

(पदार्थ और उनके गुण)

प्रस्तावना

हमारे पर्यावरण में विद्यमान विभिन्न प्रकार के पदार्थों को कक्षा 3 में छात्रों के समक्ष अभिव्यक्त किया जा चुका है। वे पदार्थों की आकृति, संरचना व अवस्था के अनुसार वर्गीकृत करने में समर्थ हो चुके हैं।

इस इकाई द्वारा छात्रः

- विशिष्ट लक्षणों के अनुसार वस्तुओं को वर्गीकृत करने,
- पदार्थों और उनसे निर्मित वस्तुओं में भेद या तुलना करने,
- उनकी कोमलता और कठोरता के अनुसार वर्गीकृत करने,
- उनकी उष्मा चालकता के अनुसार वर्गीकृत करने,
- जल/द्रव में उनके विलीन होने की क्षमता के आधार पर वर्गीकृत करने,
- पदार्थ के संघटन को समझने व अवलोकन करने में कि वह सूक्ष्म कणों से निर्मित है,
- विभिन्न पदार्थों का संघटन, उनकी जल में विलेयता को निर्धारित करता है, समझने,
- उन विविध विधियों को जिनके द्वारा ठोसों को द्रवों में से पृथक किया जा सकता है, पहचानने,
- कुछ ठोसों को, द्रवों में से वाष्पन और क्रिस्टलन द्वारा पुनः प्राप्त किया जा सकता है, जानने में, समर्थ होंगे।

### 3.1: विभिन्न वस्तुओं के विशिष्ट गुण क्या होते हैं?

केंद्रित करें: विशिष्ट लक्षणों के अनुसार वस्तुओं को वर्गीकृत करने में

(कालांश 1)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| | क्रियाकलाप 1 | |
| सामान्य विशेषताओं के आधार पर विभिन्न वस्तुओं को वर्गीकृत करना | कक्षा को छः समूहों में विभाजित कीजिए। प्रत्येक समूह को आठ वस्तुओं जैसे कि एक लकड़ी का टुकड़ा, लोहकील, माचिस की तीली, कांच की स्लाइड, रबर की गेंद, मोमबत्ती गोली और एक कागज, का सेट उपलब्ध कराइए। उन वस्तुओं का अवलोकन करने और छूने के लिए उनसे कहिए। उनसे कहिए कि इन वस्तुओं | लकड़ी का टुकड़ा, लोहेकील, रबर की गेंद, मोमवर्त्ती, गोलियाँ, कांच की स्लाइड, माचिस की तीली, कागज |

को किसी एक विशेष (सामान्य) गुण के आधार पर दो सेटों में विभाजित करें। इन सेटों में से प्रत्येक को इसी प्रकार विभाजित करवाइए जब तक हर एक वस्तु पृथक नहीं हो जाती है। प्रत्येक वस्तु के विभिन्न गुणों की सूची श्यामपट्ट पर बनाइए। छात्र उन्हें रंग, सतह की प्रकृति, आकृति, कठोरता, कोमलता, भार और मोटाई के अनुसार समूहित कर सकते हैं।
छात्रों का ध्यान इस तथ्य पर आकर्षित कीजिए कि प्रत्येक वस्तु कई विशिष्ट गुण रखती है जिनके आधार पर वह पहचानी जा सकती है।

| वस्तु | रंग | सतह की प्रकृति | आकृति | कठोर/ कोमल | भार | मोटाई |
|---|---|---|---|---|---|---|
| लोहकील | काली | चिकनी | लम्बी/ बेलनाकार | कठोर | भारी | — |

**3.2: क्या भिन्न-भिन्न वस्तुएँ एक ही अथवा भिन्न-भिन्न पदार्थों से निर्मित की जा सकती हैं?**
**केंद्रित करें: भिन्न-भिन्न वस्तुओं और पदार्थों पर, जिनसे वे निर्मित हैं**

(कालांश 1-2)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| विभिन्न वस्तुओं के सामान्य पदार्थों को जानना | क्रियाकलाप 1<br>निम्नलिखित वस्तुएँ छात्रों को दिखाइए<br>(अ) किट बाक्स का ढक्कन (ब) लोहे की छड़ (स) लोहे की कीलें (द) मोमबत्ती (इ) रबर की गेंद (फ) कक्षा की मेज (म) कुर्सी (ह) पत्थर के टुकड़े (थ) साइकिल ट्यूब (छ) बाल्टी आदि।<br>प्रत्येक वस्तु की पहचान उन पदार्थोंके आधार पर जिनसे वे निर्मित हैं कराते हुए छात्रों के सहयोग से एक सारणी तैयार कराइए। | लोहे का किट बाक्स, ढक्कन, लोहे की छड़, लोहे की कीलें, मोमबत्ती, रबर की गेंद, मेज, कुर्सी, पत्थर के टुकड़े, साइकिल ट्यूब बाल्टी |

| वस्तु का नाम | जिनसे वे निर्मित हैं |
|---|---|
| मेज | लकड़ी |
| किट का ढक्कन | टीन |
| कुर्सी | लकड़ी |
| साइकिल ट्यूब | रबर |
| लोहे की छड़ | लोहा |
| मोमबत्ती | मोम |
| गेंद | रबर |

छात्रों को यह निष्कर्ष निकालने में प्रोत्साहित कीजिए कि विभिन्न वस्तुएँ एक ही पदार्थ से निर्मित की जा सकती हैं ।

जानना कि वस्तुएं विभिन्न पदार्थों से निर्मित हैं

क्रियाकलाप 2

क्रियाकलाप 3.2.1 का स्मरण कराइए और उनका ध्यान इस तथ्य की ओर आकर्षित कीजिए कि विभिन्न वस्तुएं विभिन्न पदार्थों से निर्मित हैं । विभिन्न वस्तुओं को समान पदार्थों से निर्मित किया जा सकता है जैसे रबर की गेंद, रबर की साइकिल ट्यूब ।
एक-सी वस्तु को विभिन्न पदार्थों से निर्मित किया जा सकता है जैसे लकड़ी की कुर्सी, धातु की कुसी ।

**3.3: कोमलता और कठोरता के आधार पर पदार्थों को कैसे वर्गीकृत किया जाता है?**
**केंद्रित करें: कोमल और कठोर पदार्थों की प्रकृति पर।**

(कालांश 1-2)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| | क्रियाकलाप 1 | |
| पदार्थों के दिए गए सेट में से कठोर और कोमल पदार्थों को वर्गीकृत करना | छात्रों को एक रबर की गेंद व एक पत्थर अथवा गोली दीजिए। प्रत्येक को अपने हाथ से स्पर्श करने को कहिए, पूछिए:<br>तुम क्या अनुभव करते हो?<br>इनमें से कौन सी कठोर है और कौन सी कोमल है?<br>(इनमें से जो दबाई जा सकती है दूसरी की अपेक्षा कोमल है)<br>वस्तुओं के समूह जैसे लकड़ी का टुकड़ा, कांच की स्लाइड, कागज, कपड़ा आदि छात्रों को उपलब्ध कराइए और उनसे उन वस्तुओं को कठोर और कोमल वस्तुओं में समूहित करने को कहिए।<br>कठोरता और कोमलता की अवधारणाओं को स्पष्ट करने के लिए छात्रों से कहिए कि वे अपने पर्यावरण से पदार्थों को एकत्रित करें। | रबर की गेंद, गोली, लकड़ी का टुकड़ा कांच की स्लाइड, लोह कील, कागज, मोमबत्ती |
| | क्रियाकलाप 2 | |
| जानना कि विभिन्न पदार्थों में विभिन्न कोटि की कठोरता होती है। | छात्रों को एक लकड़ी का टुकड़ा और एक कांच की स्लाइड उपलब्ध कराइए।<br>इन वस्तुओं को एक नुकीली लोहकील से खरोचने के लिए उनसे कहिए।<br>तुम क्या अवलोकन करते हो जब लोहकील को काँच-स्लाइड और लकड़ी के टुकड़े के ऊपर खरोंचा जाता है?<br>छात्रों को यह समझने में सहायता कीजिए कि वह पदार्थ जिसमें खरोंच गहरी होती है वह उस पदार्थ जिसमें कोई खरोंच नहीं होती है अथवा हल्की खरोंच होती है, की अपेक्षा कोमल (कम कठोर) है।<br>पूछिए:<br>कांच और लकड़ी में कौन अधिक कठोर है?<br>लकड़ी और लोहे के टुकड़े छात्रों को उपलब्ध कराइए और लोहे के टुकड़े से लकड़ी के टुकड़े को खरोंचने को कहिए। | लकड़ी का टुकड़ा, कांच की स्लाइड, नुकीली लोहकील |

| | | |
|---|---|---|
| | पूछिए:<br>तुम क्या अवलोकन करते हो?<br>इस तथ्य की ओर उनका ध्यान आकर्षित कीजिए कि लोहा कठोर होने के कारण लकड़ी पर खरोंच बनाने में समर्थ है जबकि लकड़ी जो कोमल (कम कठोर) है लोहे के टुकड़े पर खरोंच नहीं बना सकती।<br>यह निष्कर्ष निकालने में उनकी सहायता कीजिए कि कठोर पदार्थ कोमल पदार्थों पर खरोंच बनाने में समर्थ होते हैं। | लकड़ी व कांच के टुकड़े |

**3.4: हम वस्तुओं को उनमें से प्रकाश के पारगमन के आधार पर कैसे वर्गीकृत करते हैं?**
**केंद्रित करें: पदार्थों के पारदर्शी गुण द्वारा उनका वर्गीकरण।**

(कालांश 2)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| जिनके आर-पार अन्य वस्तुएं देखी जा सकती हैं और जिनके आर-पार वे नहीं देखी जा सकती हैं उन वस्तुओं को वर्गीकृत करना | क्रियाकलाप 1<br>छात्रों में से किसी एक को बाहर जाने तथा दीवाल के पीछे खड़े होने हो कहिए।<br>पूछिए:<br>क्या तुम उस छात्र को देख सकते हो?<br>उसी छात्र को बंद कांच की खिड़की के पीछे खड़े होने को कहिए, अथवा कांच की स्लाइड के नीचे एक छात्र को अपनी उँगली रखने को कहिए।<br>पूछिए:<br>क्या तुम उँगली को अब देख सकते हो?<br>जब छात्र दीवार के पीछे खड़ा होता है, तब हम उसे क्यों नहीं देख सकते?<br>जब छात्र कांच की खिड़की के पीछे होता है अथवा जब उँगली कांच की स्लाइड के नीचे होती है तब हम उसे क्यों देख सकते हैं?<br>तुम इससे *क्या निष्कर्ष निकालते हो?*<br>यह निष्कर्ष निकालने में उनकी सहायता कीजिए कि पदार्थों में कुछ ऐसे पदार्थ हैं जिनके आर-पार हम देख सकते हैं और कुछ ऐसे हैं जिनके आर-पार हम देख नहीं सकते हैं। | कांच की स्लाइड |

क्रियाकलाप 2

लोहा, लकड़ी, टिन, पतली प्लास्टिक और कांच के पत्तर लीजिए।
टार्च/मोमबत्ती की सहायता से प्रत्येक के एक ओर से बारी-बारी से प्रकाश डालिए और प्रत्येक के दूसरी ओर से अवलोकन कराइए।
छात्रों से पूछिए:
जब लोहा, टिन व लकड़ी से निर्मित पत्तरों पर प्रकाश डाला जाता है तब तुम क्या देखते हो?
जब कांच और पतली प्लास्टिक के पत्तरों पर प्रकाश डाला जाता है तब तुम क्या अवलोकन करते हो?
यह निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि कुछ पदार्थ जैसे कांच, पतली प्लास्टिक इत्यादि प्रकाश को आर-पार जाने देते हैं और हम इनके आर-पार देख सकते हैं जबकि कुछ पदार्थ जैसे लकड़ी, लोहा, टिन इत्यादि अपने आर-पार प्रकाश को जाने नहीं देते है और इनके आर-पार नहीं देख सकते हैं।

ऐसे पदार्थों/वस्तुओं के उदाहरण देना जिनके आर-पार प्रकाश आ-जा सकता है और जिनके आर-पार प्रकाश नहीं आ-जा सकता हैं

लोहा, लकड़ी, पतली प्लास्टिक व कांच, टिन के पत्तर, टार्च/मोमबत्ती, माचिस

क्रियाकलाप 3

कांच का टुकड़ा, तेल में भिगोया हुआ कागज, पतला कपड़ा और लकड़ी की एक पतली प्लेट लीजिए।
प्रत्येक वस्तु के पीछे बारी-बारी से एक जलती हुई मोमबत्ती रखिए और अवलोकन कराइए।
इनमें से किस के आर-पार मोमबत्ती की लौ स्पष्टतः दृष्टिगोचर है?
इनमें से किसके आर-पार मोमबत्ती की लौ स्पष्टतः दृष्टिगोचर नहीं है?
इनमें से किस वस्तु के आर-पार मोमबत्ती की लौ धुंधली दिखाई देती हैं?
छात्रों को किट और पर्यावरण से विभिन्न वस्तुएं दीजिए। उनसे कहिए कि इन पदार्थों को समूह में वर्गीकृत करें।
जिन पदार्थों के आर-पार प्रकाश गमन कर सकता है। (पारदर्शी)
जिन पदार्थों के आर-पार प्रकाश गमन नहीं कर सकता है। (अपारदर्शी)

कांच की स्लाइड, तेल में भीगा कागज, पतला कपड़ा, लकड़ी की पतली चद्दर, मोमबत्ती, माचिस

विस्तारण 1

अपने दैनिक जीवन में उपयोग आने वाली कुछ वस्तुओं की सूची बनाने के लिए छात्रों से कहिए (1) कौन-सी पारदर्शी (2) कौन-सी अपारदर्शी है।

टिप्पणी: जिन वस्तुओं में से प्रकाश आंशिक रूप से आर-पार गमन कर सकता है और जिनमें ज्वाला धुंधली दीखती है यदि छात्र उनके बारे में पूछते हैं तब आंशिक पारदर्शी वस्तुओं के लिए "पारभासी" शब्द का परिचय कराइए।

**3.5: ऊष्मा के चालन के आधार पर हम पदार्थों को कैसे वर्गीकृत करते हैं?**

**कैंद्रित करें: ऊष्मा चालकता के आधार पर पदार्थों का वर्गीकरण**

(कालांश 1-2)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| उन पदार्थों को पहचानना जिनसे ऊष्मा का चालन होता है और जिनसे ऊष्मा का चालन नहीं होता है | क्रियाकलाप 1<br>छात्रों से कहिए कि एक धात्विक प्लेट और लकड़ी का टुकड़ा अथवा एक हथौड़ी लें। इन्हें कुछ समय तक धूप में रखें। हथौड़ी के धात्विक और लकड़ी के भाग को अथवा प्लेट एवं लकड़ी के टुकड़े को स्पर्श कराइए और उन्हें अनुभव करने दीजिए।<br>पूछिए:<br>तुम क्या अनुभव करते हो?<br>(हथौड़ी का धात्विक भाग इसके लकड़ी के भाग की अपेक्षा गर्म है)<br>लोग तलने वाले पात्रों के हत्थे लकड़ी के क्यों उपयोग करते हैं? | लकड़ी का टुकड़ा, धात्विक प्लेट, हथौड़ा |
| ऊष्मा-चालन की क्षमता के अनुसार पदार्थों का वर्गीकरण करना | क्रियाकलाप 2<br>(चेतावनी: ऊष्मा के प्रयोग छात्र शिक्षक की उपस्थित में ही करें)।<br>चालन छड़ों का सेट लीजिए और उन्हें मोटे कार्ड बोर्ड के छिद्रों में से डालिए और जल से भरे बीकर पर चित्र में दिखाए अनुसार रखिए।<br>इस बीकर को स्टैन्ड पर.तार की जाली के ऊपर रखिए। बर्नर पर रखे बीकर को कुछ समय तक गर्म कीजिए। छड़ों को गर्म करने के पूर्व और बाद में स्पर्श करने के लिए छात्रों से कहिए। | चालन छड़, बीकर, स्टैण्ड, तार की जाली, बर्नर, माचिस, छिद्र युक्त कार्डबोर्ड या लकड़ी का ढक्कन |

पूछिए:

क्या सभी छड़ें गर्म करने के बाद समान रूप से उष्ण अथवा ठंडी हैं?

कौन-सी छड़ सबसे अधिक गर्म है?

इससे कम गर्म कौन-सी छड़ है?

कुछ छड़ें अन्य छड़ों से अधिक गर्म क्यों हैं?

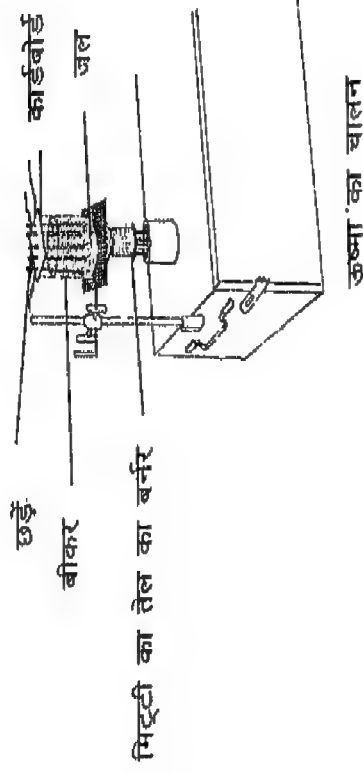
छड़ें

कार्डबोर्ड

बीकर

जल

मिट्टी का तेल का बर्नर

ऊष्मा का चालन

छड़ों की उष्णता के क्रम में छात्रों द्वारा सारिणी बनवाइए ।

यह निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि कुछ पदार्थ दूसरों की अपेक्षा उष्मा को अपने में से शीघ्रता से गमन करने देते हैं और इसलिए उन पदार्थों की छड़ें अन्य की अपेक्षा अधिक गर्म हो जाती है ।

इस क्रियाकलाप से हम क्या निष्कर्ष निकाल सकते हैं ।

लोहा और अल्यूमिनियम, कांच की अपेक्षा अपने में से उष्मा को शीघ्र गमन करने देते हैं ।

ऐसे पदार्थ जो अपने में से उष्मा को गमन करने देते हैं क्या कहलाते हैं?

ऐसे पदार्थ जो अपने में से उष्मा को गमन करने देते हैं उष्मा के अच्छे चालक कहलाते हैं जबकि जो पदार्थ अपने में से उष्मा को गमन नहीं करने देते हैं उष्मा के कुचालक कहलाते हैं ।

**विस्तारण 1**

छात्रों से कहिए कि चार-चार उदाहरण दें (1) ऊष्मा के अच्छे चालक (2) ऊष्मा के कुचालक

| ऊष्मा के अच्छे चालक | ऊष्मा के कुचालक |
|---|---|
| | |

**3.6: हथौड़ी के प्रहार का पदार्थों पर क्या प्रभाव पड़ता है?**

**केंद्रित करें: पदार्थों पर हथौड़ी के प्रहार का प्रभाव ।**

(कालांश 1)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| पदार्थ जो आसानी से टूट जाते हैं और जो आसानी से नहीं टूटते हैं, को वर्गीकृत करना | क्रियाकलाप 1<br>छात्रों से कहिए कि अपने पूर्व अनुभव के आधार पर विभिन्न वस्तुओं को तोड़ने के उदाहरण दें ।<br>कुछ दृष्टान्तों के वर्णन के बाद उनसे उन वस्तुओं की सारिणी बनाने के लिए कहिए जो उन्होंने तोड़ी हैं ।<br>अन्य ऐसी वस्तुओं के भी उदाहरण देने को कहिए जो आसानी से तोड़ी जाती है ।<br>श्यामपट्ट पर एक सूची बनाइए ।<br>उनसे उन पदार्थों के नाम पूछिए जिनसे ये वस्तुएँ बनाई जाती हैं जैसे कांच, स्लेट, संगमरमर, चीनी मिट्टी, प्लास्टिक आदि ।<br>उनसे ऐसे पदार्थों के नाम पूछिए जिनसे निर्मित वस्तुएँ नहीं टूटती हैं जैसे लकड़ी, रबर आदि । | |
| | क्रियाकलाप 2<br>कुछ लोहे की कीलें, कांच के टुकड़े, चीनी मिट्टी अथवा चीनी मिट्टी की टूटी वस्तुएँ टिन अथवा ताँबा (तार अथवा पत्र), ईंट और खड़िया के टुकड़े लीजिए ।<br>छात्रों से कहिए कि इन टुकड़ों में प्रत्येक को हथौड़ी से प्रहार करें और अवलोकन करें ।<br>क्या होता है? | लोहे की कीलें, कांच (पत्र अथवा तार) चीनी मिट्टी, टिन, ताँबा, ईंट खड़िया हथौड़ा |

छात्रों से पूछिए:
इन वस्तुओं में से कौन-सी आसानी से टूट जाती हैं?
इन वस्तुओं में से कौन-सी नहीं टूटती हैं?

छात्रों से उनके प्रेक्षणों की निम्नलिखित सारणी बनवाइए।

| सामग्री | टूटने योग्य | न टूटने योग्य |
|---|---|---|
| कांच | ✓ | ✗ |
| लोहा | ✗ | ✓ |
| ईंट | ✓ | ✗ |
| तांबा | ✗ | ✓ |
| खड़िया | ✓ | ✗ |
| लकड़ी | ✓ | ✗ |

छात्रों से पूछिए:
अल्यूमिनियम या कांच के पात्र में से कौन-सा आसानी से टूट जाता है?
घरेलू बर्तन जैसे चीनी मिट्टी के कप, गिलास, मिट्टी के घड़े जो टूटने योग्य हैं फिर भी उपयोग में क्यों हैं? यह समझने में छात्रों की सहायता कीजिए कि यद्यपि कुछ वस्तुएंटूटने योग्य हैं फिर भी वे सस्ती, स्वास्थ्यकर, ऊष्मा की कुचालक है और कलात्मक बनाई जा सकती है इसलिए वे अभी भी उपयोग में हैं। ऐसे तरीके और साधन सोच निकालने में छात्रों की सहायता कीजिए जिनसे टूटने योग्य वस्तुओं को सुरक्षा पूर्वक रखा जा सके।

**3.7: क्या सभी पदार्थ जल में विलीन हो जाते हैं?**

**केंद्रित करें: जल में विलीन होने की क्षमता के आधार पर पदार्थो को वर्गीकृत करना**

(कालांश 2-3)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| उन पदार्थों को पहचानना जो जल में शीघ्र विलीन हो जाते हैं अथवा विलीन नहीं होते हैं | क्रियाकलाप 1<br>छात्रों के पूर्व अनुभव के आधार पर पूछिए:<br>क्या होता है जब हम चाय, दूध अथवा काफी में शक्कर या गुड़ डालकर विलोडन करते हैं?<br>(शक्कर अदृश्य या विलीन हो जाती है)।<br>पांच विभिन्न परखनलियों में शक्कर, नमक, लकड़ी का बुरादा, रेत और लोहे की छीलन जैसे पदार्थों की कम मात्रा लीजिए और प्रत्येक परखनली में कुछ जल उड़ेलिए। कुछ समय तक परखनलियों को तेजी से हिलाइए। अब उन्हें प्रत्येक परखनली में हिलाने के प्रभाव का अवलोकन करने दीजिए।<br>पूछिए:<br>किस परखनली में ठोस की मात्रा कम हो जाती है?<br>किस परखनली में ठोस पूर्णतः अदृश्य हो जाता है?<br>किन परखनलियों में ठोस बिना किसी परिवर्तन के शेष रहता है?<br>शक्कर और नमक का क्या हुआ?<br>(ये पदार्थ पूर्णतः विलीन हो गए)।<br>उनसे कहिए कि पदार्थ जो पूर्णतः विलीन हो जाते है विलेय पदार्थ कहलाते हैं।<br>टिप्पणीः ठोस जो द्रव में विलीन हो जाता है, विलेय कहलाता है। द्रव जिसमें विलेय विलीन हो जाता है, विलायक कहलाता है। विलीन पदार्थ (विलेय) और द्रव (विलायक) के मिश्रण को विलयन कहते हैं।<br>विलेय+विलायक=विलयन<br>उनसे कहिए कि लकड़ी का बुरादा, रेत और लोहे की छीलनयुक्त परखनलियों का अवलोकन करें।<br>पूछिए:<br>रेत और लोहे की छीलन का क्या होता है?<br>(वे पेंदी में बैठ जाते हैं)<br>लकड़ी के बुरादे का क्या होता है? | चीनी, नमक, बुरादा, रेत, लोहे की छीलन, पांच परखनली, जल |

(लकड़ी का बुरादा जल पर तैरता है)
क्या वे परिमाण में घट जाते हैं?
(नहीं, वे वैसे ही शेष रहते हैं जैसे वे होते हैं)

उनसे कहिए कि ऐसे पदार्थ जो जल में विलीन नहीं होते हैं, अविलेय पदार्थ कहलाते हैं।
छात्रों से कहिए कि वे अपने अवलोकन निम्नानुसार अंकित करें।

| पदार्थ का नाम | विलेय | अविलेय |
|---|---|---|
| शक्कर | ✓ | ✗ |
| लोहे की छीलन | ✗ | ✓ |
| नमक | ✓ | ✗ |
| रेत | ✗ | ✓ |
| लकड़ी का बुरादा | ✗ | ✓ |

क्रियाकलाप 2

ठोस, जो जल में विलेय या अविलेय है, के उदाहरण देना

छात्रों से कहिए कि अन्य पदार्थ एकत्रित करें और यह मालूम करें कि कौन-से पदार्थ जल में शीघ्र विलीन हो जाते हैं और कौन से पदार्थ विलीन नहीं होते हैं पदार्थों के नाम क्रियाकलाप 3.7.1 की सारिणी में लिखवाइए।

क्रियाकलाप 3

जल के अलावा अन्य विलायकों के उदाहरण देना

छात्रों का ध्यान इस ओर आकर्षित कीजिए कि ऐसे कई ठोस हैं जो जल में विलीन नहीं हो सकते है लेकिन वे अन्य विलायकों में विलेय हैं।

तारकोल, मोम, ग्रीस, पेट्रोल, मिट्टी का तेल, तारपीन का तेल, जल

छात्रों के साथ परिचर्चा कीजिए कि मिट्टी का तेल/पेट्रोल/तारपीन का तेल जैसे द्रवों में पदार्थों के विलीन हो जाने का गुण, ग्रीस/तारकोल/आयल पेंट से गंदे हुए हमारे हाथों को साफ करने में सहायक होते हैं।
छात्रों से कहिए कि ऐसे ठोसों की सारणी बनाएँ जो जल, मिट्टी का तेल पेट्रोल और तारपीन के तेल में विलेय हैं।

| सामग्री का नाम | जल में विलेय | मिट्टी के तेल में विलेय | पैट्रोल में विलेय | तारपीन के तेल में विलेय |
|---|---|---|---|---|
| पेंट | x | ✓ | ✓ | ✓ |
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### 3.8: क्या पदार्थ अतिसूक्ष्म कणों से निर्मित हैं?
कैंद्रित करें: पदार्थ का संघटन

(कालांश 2)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| | क्रियाकलाप 1 | |
| यह जानना कि ठोस का बड़ा टुकड़ा छोटे टुकड़ों में तोड़ा जा सकता है | खड़िया का एक टुकड़ा लीजिए और एक हथौड़ी से उसे हल्के प्रहार से छोटे-छोटे टुकड़ों में तोड़िये। <br>पूछिए: <br>तुम क्या अवलोकन करते हो जब खड़िया के एक बड़े टुकड़े को हथौड़ी का हल्का प्रहार किया जाता है? <br>खड़िया के टुकड़े को चूर्ण में पीसिए। <br>चूर्णित खड़िया को छात्रों द्वारा अवलोकन करने दीजिए और पूछिए कणों के आकार में तुम क्या परिवर्तन देखते हो? <br>कपड़े का एक टुकड़ा लीजिए और चूर्ण की बहुत छोटे कणों में प्राप्त करने के लिए छानिए। <br>पूछिए: <br>छान लिए जाने पर तुम कणों के आकार में क्या परिवर्तन देखते हो? <br>इस चूर्ण को कागज पर रखिए और छात्रों से कहिए कि इसकी हैंडलैंस से द्वारा अवलोकन करें। <br>पूछिए: <br>तुम क्या अवलोकन करते हो? <br>यह निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि खड़िया के टुकड़े को ऐसे अति सूक्ष्म कणों में विभाजित किया जा सकता है जिन्हें बिना किसी आवर्धक लेंस की सहायता से नहीं देखा जा सकता है। | खड़िया, हथौड़ी, कपड़े का टुकड़ा, आवर्धक लेंस |

| | | |
|---|---|---|
| यह जानना कि पदार्थ को ऐसे अतिसूक्ष्म कणों मे तोड़ा जा सकता है जो इतने छोटे होते हैं कि प्रत्येक कण को खाली आंख से नहीं देखा जा सकता है | क्रियाकलाप 2<br>पोटेशियम परमेंगनेट के कुछ कण लीजिए और उन्हें हथौड़ी से पीसिए ।<br>सुई की नोक पर पोटेशियम परमेंगनेट की कुछ मात्रा लीजिए ।<br>सुई को बीकर में लिए गए जल में डुबोइए । और छात्रों से कहिए कि इसका अवलोकन करें<br>यह अवलोकन करने में छात्रों की सहायता कीजिए कि पोटेशियम परमेंगनेट के छोटे-छोटे कण बीकर में लिए गए जल में इनसे भी छोटे कणों के रूप में फैलते जाते हैं और जल धीरे-धीरे गुलाबी होता जाता है । पोटेशियम परमेंगनेट के कणों को आवर्धक लेंस द्वारा देखने के लिए छात्रों से कहिए ।<br>पूछिएः<br>क्या तुम कणों को देख सकते हो?<br>तुम क्या निष्कर्ष निकालते हो?<br>यह निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि सूक्ष्म कण मानव नेत्र के लिए अदृश्य होते हैं जो और भी सूक्ष्म कणों में विभाजित किए जा सकते हैं ।<br>टिप्पणीः 3000 वर्ष पूर्व भारत के ऋषि कणांद ने यह प्रतिपादित किया था कि प्रत्येक पदार्थ अति सूक्ष्म व अदृश्य कणों से निर्मित हैं । | पोटेशियम परमेंगनेट, बीकर, हैंडलैंस सुई, जल |

**3.9: क्या जल में विलीन होने पर पदार्थ सूक्ष्म कणों में विभाजित हो जाता है?**
**केंद्रित करें: जल में विलीन होने वाले पदार्थ का संघठन ।**

(कालांश 2)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| यह जानना कि कुछ ठोस पदार्थ जल में विलीन होने पर छोटे कणों में टूट जाते हैं | क्रियाकलाप 1<br>छात्रों से कहिए कि तीन परखनलियों क, ख, और ग में लगभग आधे भाग तक जल भरें ।<br>इन तीनों परखनलियों में क्रमशः थोड़ा नमक, खड़िया के टुकड़े और मिट्टी का ढेला डालें ।प्रत्येक परखनली को थोड़ी देर तक हिलाएँ । कुछ समय तक उन्हें पेंदी में बैठने दीजिए । परखनली क में नमक का अवलोकन कराइए ।<br>पूछिएः<br>नमक का क्या होता है? | तीन परखनलियाँ, नमक, खड़िया मिट्टी |

क्या नमक दिखाई देता है?
उनसे कहिए कि परखनली ख में खड़िया का अवलोकन करें ।
पूछिए:
क्या खड़िया विलीन हो चुकी है या छोटे-छोटे कणों में विभाजित हो चुकी है?
द्रव का रंग क्या है?
क्या खड़िया का कुछ चूर्ण पेंदी में बैठ चुका है?
उन्हें परखनली ग में मिट्टी का अवलाकेन करने दीजिए ।
पूछिए:
मिट्टी के ढेले का क्या हुआ?
क्या यह विलीन हो गया है या नहीं?
यह निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि नमक (यानि जल में विलेय ठोस) विलायक में छोटे अदृश्य कणों में टूट जाता है और द्रव में एक समान रूप से पूरी तरह फैल जाता है । द्रव और ठोस पदार्थ का यह मिश्रण विलयन कहलाता है ।

खड़िया के प्रकरण में यह देखने में आता है कि खड़िया बहुत छोटे कणों में नहीं टूटती इसलिए निलम्बित कण दीखते हैं । इस प्रकार का मिश्रण जहाँ ठोस के कण द्रव में निलम्बित रहते हैं, निलम्बन कहलाता है । मिट्टी के प्रकरण में जल स्वच्छ है क्योंकि मिट्टी के कण जल में विलीन नहीं होते हैं और पेंदी में बैठ जाते हैं ।
उपयुक्त निर्णयों से यह निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि:
– सभी ठोस किसी द्रव में छोटे-छोटे कणों में विभाजित नहीं होंगे ।
– ठोस जो द्रव में विलीन हो जाते हैं अति सूक्ष्म अदृश्य कणों में विभाजित हो जाते है और समूचे द्रव में समानरूप से फैल जाते है ।

जानना कि स्वच्छ विलयन में सूक्ष्म कण अदृश्य कणों में टूट जाते हैं और समूचे द्रव में समान रूप से फैल जाते हैं

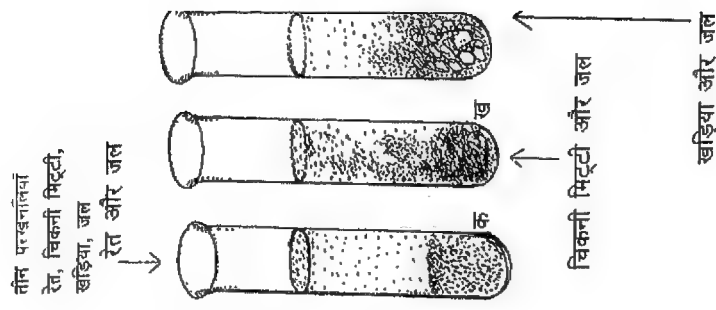
दैनिक जीवन में कुछ विलयनों जैसे दूध में शक्कर, जल में नमक के उदाहरण यह दिखलाते हुए दीजिए कि कण समूचे द्रव में समान रूप से फैल गए हैं ।
समूचे विलयन का स्वाद एक-सा होता है ।
अन्य उदाहरण बीकर के जल में पोटेशियम परमेंगनेट के रंग का अवलोकन कराकर दिया जा सकता है । समूचे द्रव का रंग एक समान रहता है ।

नमक, शक्कर, जल, दूध, पोटेशियम परमेंगनेट

## 3.10: द्रवों में से ठोसों को हम कैसे पृथक करते हैं?

केंद्रित करें: द्रवों में से ठोसों का पृथक्करण

(कालांश 2-3

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| किसी द्रव में से अविलेय ठोस को अवसादन, निस्तारण और निस्यन्दन द्वारा पृथक करना | क्रियाकलाप 1<br>छात्रों से कहिए कि जल से लगभग आधी भरी हुई तीन परखनलियाँ क, ख, और ग लें।<br>प्रत्येक में क्रमशः कम परिमाण की रेत, मिट्टी और खड़िया डालने के लिए कहिए।<br>उन्हें कुछ समय तक विलोडित करने और पेंदी में बैठ जाने के लिए छोड़ देने के लिए कहिए।<br>परखनली 'क' जिसमें रेत है का अवलोकन करने दीजिए।<br>पूछिए:<br>तुम क्या अवलोकन करते हो?<br>(रेत पेंदी में बैठ चुकी है और जल स्वच्छ है)<br>रेत पेंदी में क्यों बैठ गई है?<br>(रेत जल में अविलेय है। रेत जल की अपेक्षा भारी है)<br>स्पष्ट कीजिए कि अविलेय ठोसों के पेंदी में बैठ जाने की यह क्रिया अवसादन (नीचे बैठ जाना) कहलाती है।<br>मिट्टी युक्त परखनली 'ख' का अवलोकन कराइए और पूछिए:<br>मिट्टी का क्या होता है?<br>(मिट्टी का कुछ भाग नीचे पेंदी में बैठ जाता है जबकि शेष जल में निलम्बित रहता है। जल स्वच्छ नहीं है। यह गंदला है)।<br>यह परखनली को इस स्थिति में और बना रहने देने को कहिए।<br>अवलोकन कराइए क्या होता है?<br>(धीरे-धीरे और अधिक चिकनी मिट्टी नीचे बैठती जाती है)<br>पूछिए:<br>उपयुक्त अवलोकनों से तुम क्या निष्कर्ष निकालते हो?<br>इस तथ्य की ओर उनका ध्यान आकर्षित कीजिए कि कुछ प्रकरणों में अन्य प्रकरणों की अपेक्षा अवसादन तीव्रता से होता है। | तीन परखनलियाँ<br>रेत, चिकनी मिट्टी, खड़िया, जल<br>रेत और जल<br>क<br>ख<br>चिकनी मिट्टी और जल<br>खड़िया और जल |

क्रियाकलाप 2

दिन प्रति दिन के जीवन से कुछ ऐसे उदाहरण देने के लिए छात्रों से कहिए
जहाँ अवसादन संभव है या किया जाता है जैसे चाय की पत्तियों का नीचे बैठते जाना, दालों या चावलों को धोना ।

पिछले क्रियाकलाप 3.10.1 की 'क' एवं 'ख' परखनलियों पर विचार कीजिए ।

पूछिए:

जल में रेत और चिकनी मिट्टी पृथक करने का सरलतम तरीका क्या होगा?

परखनली ''क'' और ''ख'' को लेने के लिए कहिए । धीरे-धीरे दोनों में से जल को इस प्रकार गिरा देने दीजिए, कि ठोस विचलित न हो ।

पूछिए:

क्या तुम द्रव में से ठोस को पृथक करने में समर्थ हो चुके हो?

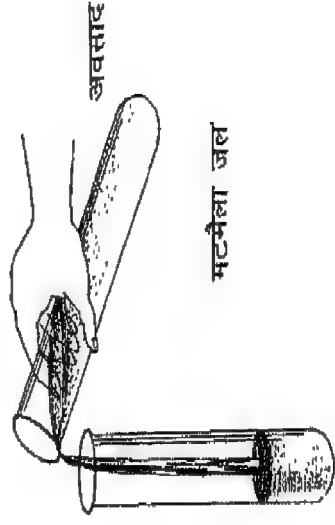
यह प्रक्रिया क्या कहलाती है?

(इस प्रक्रिया को निस्तारण (निथारना) कहते हैं)

यदि ठोस द्रव में तैरता हुआ अथवा निलम्बित है, तो क्या तुम द्रव को ठोस पदार्थ बिना लिए निस्तारित कर सकते हो?

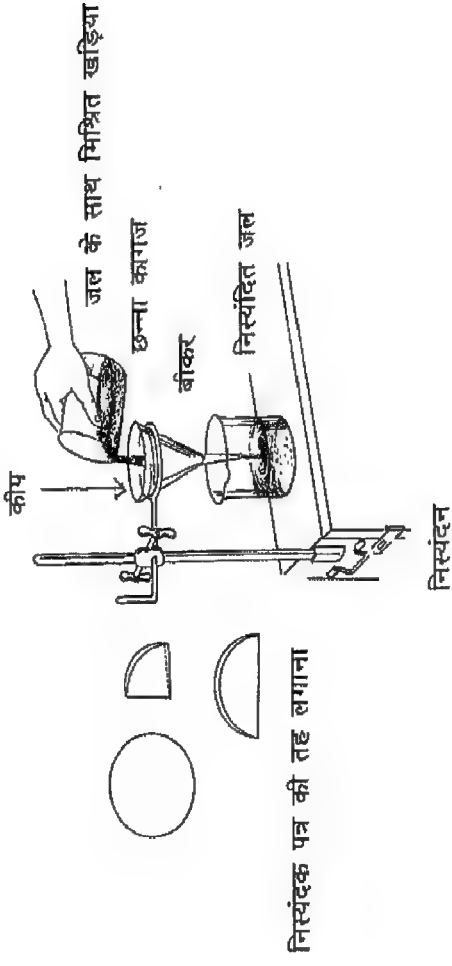
निस्तारण-प्रक्रिया का उपयोग हम कब करते हैं?

छात्रों को यह समझने में सहायता कीजिए कि निस्तारण तभी संभव होता है जब ठोस अविलेय है और पेंदी में नीचे बैठ जाता है ।

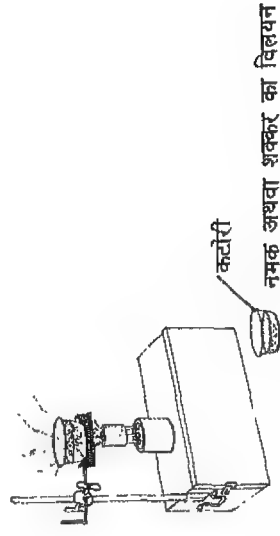
निस्तारण

कीप, स्टैंड, बीकर, छन्ना कागज, छन्ना, क्लैम्प, पानी में चाक का मिश्रण

खड़िया युक्त परखनली "ग" का अवलोकन कराइए।
पूछिएः
परखनली में क्या देखते हो?
(जल स्वच्छ नहीं है, समूचे द्रव में खड़िया के कण निलम्बित हैं)
क्या जल में से अवसादन और निस्तारण प्रक्रिया से खड़िया को पृथक किया जा सकता है?
इस कार्य के लिए ये प्रक्रियाएँ क्यों प्रयुक्त नहीं की जा सकती है?
एक कीप लीजिए और उसे स्टैंड पर लैम्प की सहायता से लगाइए। एक बीकर उसके नीचे रखिए।
चित्र में दिखाए गए अनुसार एक छन्ना कागज लपेटिए और उसे कीप में लगाइए।
पूछिए —
तुम क्या अवलोकन करते हो?
यह निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि स्वच्छ जल छन्ना कागज से निस्यन्दित होकर बीकर में एकत्रित होता जाता है। निलम्बित खड़िया का चूर्ण छन्ना कागज पर बैठता जाता है।
यह प्रक्रिया क्या कहलाती है?
(इस विधि द्वारा किसी द्रव से ठोस को पृथक करने को निस्यंदन (छानना) कहते हैं)।

निस्यंदक पत्र की तह लगाना

निस्यंदन

**3.11: विलयन में से विलेय ठोस को हम पुनः कैसे प्राप्त करते हैं?**
**केंद्रित करें: वाष्पन द्वारा द्रवों में से ठोसों की पुनः प्राप्ति ।**

(कालांश 2)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
| --- | --- | --- |
| जानना कि द्रव में विलेय ठोसों को वाष्पन की प्रक्रिया द्वारा पृथक किया जा सकता है | क्रियाकलाप 1<br>एक कटोरी में नमक का विलयन तथा दूसरी कटोरी में शक्कर का विलयन (जल में विलीन शक्कर) लीजिए चित्र में दिखाए अनुसार प्रत्येक कटोरी को गर्म कीजिए ।<br>पूछिए:<br>तुम क्या देखते हो?<br>(द्रव धीरे-धीरे गर्म होकर उबलकर अदृश्य वाष्पित हो रहा है)<br>तब तक गर्म करते जाइए जब तक पूर्णतः वाष्पित नहीं हो जाता<br>पूछिए:<br>तुम क्या अवलोकन करते हो?<br>(नमक कटोरी में बच रहता है)<br>नमक के विलयन में से नमक को अवसादन, निस्तारण या निस्पन्दन द्वारा पृथक क्यों नहीं किया जा सकता है? छात्रों से परिचर्चा कीजिए और उन्हें समझाइए कि यदि ठोस, द्रव में विलेय हो तब उसे निस्तारण अथवा निस्यंदन द्वारा पृथक नहीं किया जा सकता है । चूंकि विलयन में ठोस पदार्थ के कण बहुत छोटे व अदृश्य होते हैं, वे भी छन्ना कागज के छिद्रों में से द्रव के साथ गमन कर जाते हैं । | स्टेंड, बर्नर, तारकी जाली दो कटोरियां नमक तथा शक्कर. |

वाष्पन द्वारा विलयन में से ठोस का पृथक्करण

सामान्य पदार्थों के रासायनिक नामों का उल्लेख करना

क्रियाकलाप 2

श्याम पट पर ऐसे पदार्थों की सूची बनाइए जो सामान्यतः उपयोग में आते हैं और उनके रासायनिक नाम लिख दीजिए । छात्रों से उनके नाम का उच्चारण कराइए ।

| सामान्य नाम | रासायनिक नाम |
|---|---|
| नमक | सोडियम क्लोराइड |
| शक्कर | सुक्रोस |
| चूना पत्थर/संगमरमर/चाक | कैल्शियम कार्बोनेट |
| धावन सोड़ा | सोडियम बाइ-कार्बोनेट |
| नौसादर | अमोनियम क्लोराइड |
| प्लास्टर आफ पेरिस | कैल्सियम सल्फेट |

विस्तारण 1

सामान्य जल तथा समुद्री जल में अन्तर के सम्बन्ध में छात्रों से परिचर्चा कीजिए ।

पूछिए:

समुद्री जल से नमक कैसे पृथक किया जाता है?

समुद्री जल में नमक विलेय रहता है । उथली व खुली क्यारियों (भूमि) में समुद्री जल को सूर्य की ऊष्मा से वाष्पित होने के लिए छोड़ दिया जाता है । जल वाष्पित हो जाता है और नमक शेष रह जाता है ।

पूछिए:

हम जल में से चिकनी मिट्टी या रेत को निस्पन्दन द्वारा पृथक क्यों करते हैं?

क्या द्रवों में से सभी विलेय पदार्थों को निस्पन्दन द्वारा पृथक किया जा सकता है?

तीन विधियों जैसे अवसादन, निस्तारण और निस्पन्दन में से कौन-सी सर्वाधिक प्रभावी है?

द्रवों में से अविलेय ठोसों को पृथक करने के लिए घरों में हम छन्ना कागज के बजाय अन्य सामग्री उपयोग में लाते हैं? जैसे चाय में से चाय पत्ती, उबले चावलों में से श्वेतसार जल (माँड) उबलते तेल में तली हुई खाद्य सामग्री आदि ।

### विस्तारण 2

विभिन्न ठोस पदार्थों जैसे खड़िया, चिकनी मिट्टी, रेत, लोहे की छीलन आदि के अवसादन की दर की तुलना करने के लिए छात्रों से कहा जा सकता है। निम्नानुसार सारणी भरवाइए।

| पदार्थ का नाम | समान परिमाण के पदार्थों द्वारा अवसादन हेतु लिया गया समय |
|---|---|
| | |

### विस्तारण 3

शक्कर के क्रिस्टल, कागज, हैन्डलेन्स

शक्कर के क्रिस्टल (रवे) कक्षा में दिखाइए और छात्रों का ध्यान उन क्रिस्टलों की विशिष्ट आकृति की ओर आकर्षित कीजिए।

उनसे कहिए कि हिम तल भी क्रिस्टल हैं। कई बार तह किए गए कागज से चित्र में दिखाई विभिन्न आकृतियों की भाँति हिम तल के नमूने काटने के लिए उन से कहिए।

छात्रों से सममिति की अवधारणा स्पष्ट कीजिए और उन्हें बताइए कि क्रिस्टलों को जब आवर्धक लैंस द्वारा देखा जाता है तब उनमें ऐसी विभिन्न सुन्दर आकृतियाँ दिखाई देंगी।

शक्कर के क्रिस्टल

सममित आकृतियाँ

हिमतूल का आवर्धित दृश्य

# इकाई 4: वायु, जल और मौसम
## (मौसम और इसका जीवन पर प्रभाव)

प्रस्तावना

ऋतुओं और मौसम में होने वाले परिवर्तनों से छात्र भली भांति परिचित हैं । वे वायु, पवन और वर्षा तथा ऋतुओं पर इनके प्रभाव से भी अवगत हैं । उन्हें यह भी ज्ञान है कि ऋतुओं में परिवर्तन से जन जीवन, पैदावार, पशु और पौधे प्रभावित होते हैं ।

इस इकाई द्वारा छात्रः
- पृथ्वी पर जीवन के लिए तथा मौसम निर्धारण में सूर्य का महत्व पहचानने,
- वाष्पन और द्रवण में विभेद करने,
- जल के वाष्पन दर को प्रभावित करने वाले कारकों को सामान्य नियम का रूप देने,
- जल को ठंडा करने का परिणाम तथा मौसम को बदलने में जल वाष्प के द्रवण की भूमिका समझने,
- जन-जीवन तथा पैदावार पर मौसम के प्रभाव को पहचानने में, समर्थ होंगे ।

**4.1: सूर्य की क्या भूमिका है?**

**केंद्रित करें: पृथ्वी पर जीवन के लिए तथा मौसम निर्धारण में सूर्य के प्रकाश का महत्व**

(कालांश 1-2)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| दिन में पृथ्वी की सतह को प्रकाश एवं गर्मी प्रदान करने में सूर्य की भूमिका की पहचान कराना | क्रियाकलाप 1<br>छात्र मौसम में होने वाले परिवर्तनों से अवगत हैं और उन्हें यह भी ज्ञान है कि मौसम हमारे दैनिक जीवन को किस प्रकार प्रभावित करता है । वे यह भी जानते हैं कि सूर्य, पवन, आकाश में बादल, वर्षा मौसम को निर्धारित करते हैं । प्रश्न पूछकर उन्हें दैनिक जीवन के अनुभव का स्मरण दिलाइए कि दिन में सूर्य हमें गरमी और प्रकाश प्रदान करता है ।<br>पूछिएः<br>हमें दिन/रात में अपने घर में प्रकाश किस प्रकार मिलता है?<br>कक्षा प्रारम्भ करने के पूर्व लोहे अथवा पत्थर के 5 या 6 टुकड़ों को लगभग 2 या 3 घण्टे तक धूप में तथा कुछ टुकड़ों को कक्षा के किसी कोने मे रखिए । | पत्थर/लोहे के टुकड़े |

किसी छात्र के बाहर धूप में रखे सभी लोहे/पत्थर के टुकड़ों को लाकर कक्षा में मेज पर रखने को कहिए। दूसरे छात्र से कक्षा में रखे पत्थर/लोहे के टुकड़ों को भी उसी मेज पर रखने को कहिए। कक्षा के सभी छात्रों से कहिए कि धूप में रखे टुकड़ों तथा कक्षा के एक कोने से लाए गए टुकड़ों को स्पर्श करें।

पूछिए:

दोनों स्थानों पर रखे टुकड़ों को स्पर्श करने पर तुम क्या अन्तर अनुभव करते हो?

(धूप में रखे गए टुकड़े गरम हैं)

धूप में रखे टुकड़े गरम क्यों हो जाते हैं? (सूर्य से प्राप्त गरमी के कारण)

धूप वाले दिन नंगे पाँव सड़क पर चलने में तुम कैसा अनुभव करते हो?

यह निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि सूर्य हमें दिन में प्रकाश और गरमी प्रदान करता है।

क्रियाकलाप 2

ग्रीष्म तथा शीत ऋतु के दिनों में सूर्य से प्राप्त गरमी का तुलनात्मक ज्ञान कराना

विचार विमर्श द्वारा छात्रों को विभिन्न ऋतुओं में सूर्य से प्राप्त गरमी के बारे में उनके अनुभवों का स्मरण दिलाइए।

एक वर्ष में कौन-कौन सी ऋतुएँ होती हैं?

किस ऋतु में दिन ठंडे होते है?

किस ऋतु में दिन गरम होते हैं?

किस ऋतु में सूर्य से अधिक गरमी प्राप्त होती है?

छात्रों से एक सूची बनाने को कहिए।

| ऋतु | दिन | रात्रि |
|---|---|---|
| | | |

इस प्रकार छात्रों से यह तथ्य निकलवाइए कि ग्रीष्म-ऋतु में दिन शीत ऋतु की अपेक्षा अधिक गरम होते हैं क्योंकि ग्रीष्म ऋतु में शीत ऋतु की अपेक्षा सूर्य से अधिक गरमी प्राप्त होती है।

अब यह स्पष्ट कीजिए कि ग्रीष्म ऋतु में शीत ऋतु की अपेक्षा सूर्य हमारे सिर पर सीधा पड़ता है।

ग्रीष्म ऋतु में शीत ऋतु की अपेक्षा दिन अधिक गर्म होने के कारण का ज्ञान कराना

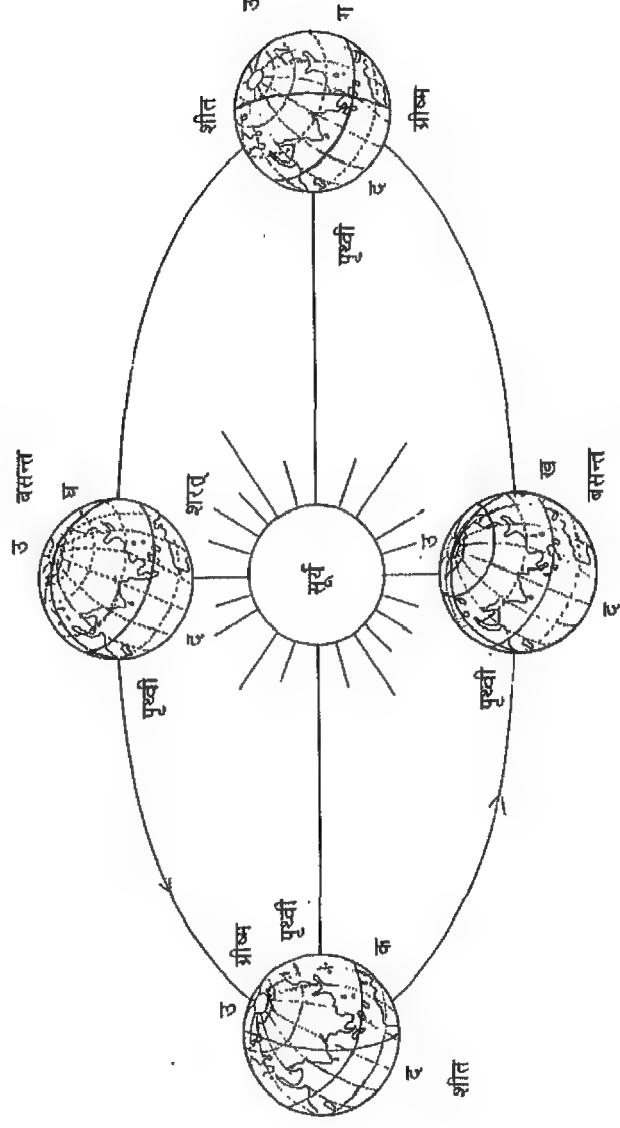
क्रियाकलाप 3

ग्रीष्म और शीत ऋतु में सूर्य की स्थिति प्रदर्शित करने वाले क्रियाकलाप 7.5.2 में दिए गए चित्र को छात्रों को दिखाकर उनसे पूछिए:

ग्रीष्म और शीत ऋतु में पृथ्वी के किसी भाग पर सूर्य द्वारा उत्पन्न गरमी सूर्य की स्थिति के अनुसार किस प्रकार प्रभावित होती है?

इस प्रकार छात्रों द्वारा यह निष्कर्ष निकालने में सहायता कीजिए कि ग्रीष्म ऋतु में शीत ऋतु की अपेक्षा सूर्य पृथ्वी को अधिक गरमी प्रदान करता है,

क्योंकि ग्रीष्म ऋतु में शीत ऋतु की अपेक्षा सूर्य हमारे सिर के ठीक ऊपर होता है।

ग्रीष्म और शीत ऋतु में सूर्य की स्थिति प्रदर्शित करने वाले चित्र

ऋतुओं का होना का प्रदर्शन

यह पहचान कराना कि ग्रीष्म ऋतु में शीत ऋतु की अपेक्षा दिन बड़े होते हैं

क्रियाकलाप 4

छात्रों को निर्देश दीजिए कि समाचार पत्रों से सूर्योदय और सूर्यास्त का समय नोट करें । उन्हें निर्देश दीजिए कि वे ग्रीष्म और शीत ऋतु में सूर्योदय और सूर्यास्त के समय की तुलना करें ।

यह निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि ग्रीष्म ऋतु में शीत ऋतु की अपेक्षा अधिक गरमी प्राप्त होती है क्योंकि ग्रीष्म ऋतु में शीत ऋतु की अपेक्षा दिन की अवधि अधिक होती है, अर्थात दिन बड़े होते हैं ।

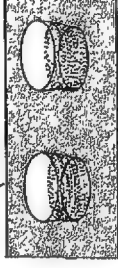
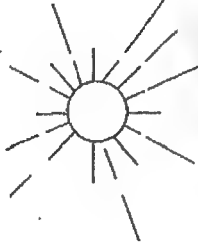
सूर्योदय तथा सूर्यास्त का समय देने वाले समाचार पत्र

दिन और रात में पृथ्वी की सतह पर भूमि और जल के क्रमशः गरम और ठंड होने की दर की तुलनात्मक ज्ञान कराना

क्रियाकलाप 5

एक ही प्रकार के दो बर्तन (कटोरी) लीजिए । किसी छात्र से कहिए कि तीन चौथाई (3/4) तक एक कटोरी में बालू तथा दूसरी कटोरी में पानी भरें और उन्हें लगभग एक घंटे तक धूप में रखें ताकि वे काफी गरम हो जाएं। (यह ध्यान रखा जाय कि बालू छाया के स्थान से ही लिया जाय । दोनों पदार्थों का ताप समान होना चाहिए) । कक्षा के छात्रों से कहिए कि बारी-बारी से बाहर जाकर बालू और पानी को छूकर उनकी गरमाहट अनुभव करें ।

दो कटोरी अथवा एक प्रकार के दो बर्तन, बालू और पानी

पूछिए:

बालू और पानी की गरमाहट में तुम क्या अंतर अनुभव करते हो?

बालू और पानी में कौन अधिक गरम है?

बालू अथवा पानी, कौन-सी वस्तु धूप में तेजी से गरम होती है?

यह निष्कर्ष निकलवाने में छात्रों की सहायता कीजिए कि दिन में बालू पानी की अपेक्षा शीघ्रता से गरम होती है । अब इन कटोरियों को छाया में कमरे के अन्दर लगभग एक घंटे तक रखने को कहिए ताकि बालू काफी ठंड़ी हो जाए । (इस अवधि में छात्रों को किसी दूसरे क्रियाकलाप में लगाए रहिए और उन्हें बता दीजिए कि अगली

जांच का कार्य एक घंटे पश्चात् किया जाएगा) । प्रत्येक छात्र से बालू और पानी को छूकर उनकी गरमाहट अनुभव करने को कहिए ।

पूछिएः

बालू और पानी की गरमाहट में तुम क्या अंतर अनुभव करते हो?

बालू और पानी में कौन-सी वस्तु अधिक ठंडी है?

इनमें (बालू अथवा पानी) कौन-सी वस्तु शीघ्र ठंडी होती है ।

छात्रों से कहिये कि इसी क्रियाकलाप को अपने घर पर पुनः करें । उनसे कहिए कि वे कटोरियों को रातभर रखने के पश्चात् अगले दिन परिणाम की सूचना दें ।

यह निष्कर्ष निकालने के लिए छात्रों को प्रोत्साहित कीजिए कि छाया में पानी की अपेक्षा बालू शीघ्रता से ठंडी होती है ।

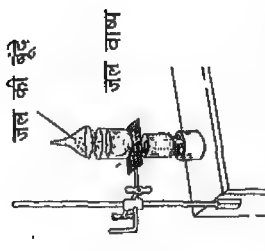
सविस्तार समझाइए कि भूमि पानी की अपेक्षा अधिक शीघ्रता से गरम और ठंडी होती है । यही कारण है कि समुद्र के निकट के स्थान दूर के स्थानों की तुलना में ग्रीष्म ऋतु में अधिक ठंडे और शीत ऋतु में अधिक गरम होते हैं । इसी कारण से रेगिस्तान में रात बहुत ठंडी और दिन बहुत गरम होते हैं ।

**4.2:** वाष्पन और द्रवण में क्या अन्तर है?

केंद्रित करें: वाष्पन और द्रवण में अन्तर

(कालांश 2)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| | क्रियाकलाप 1 | |
| यह पहचान कराना कि वाष्पन द्वारा जल, वाष्प में बदलकर वायु में मिल जाती है तथा द्रवण द्वारा जल वाष्प जल में बदल जाती है | एक बीकर लीजिए और उसमें थोड़ा-सा पानी डालिए । तत्पश्चात इसे चित्रानुसार एक स्टैंड पर रखकर इसके नीचे एक मिट्टी के तेल का बर्नर रखिए और उसे जला दीजिए । बीकर में पानी के उबलने तक छात्रों को इसे ध्यान से देखते रहने को कहिए । (वाष्पन और उबलना) | बीकर, स्टैंड, मिट्टी के तेल का बर्नर, कांच की कीप, पानी, तार की जाली, दियासलाई |

कांच की एक कीप (फनल) लीजिए और इसे पोंछकर तथा सुखाकर चित्रानुसार बीकर के ऊपर रखिए । छात्रों से कहिए कि निचली सतह से बूंद बूंद गिरते पानी को ध्यान से देखें (द्रवण) । छात्रों से पूछिए कि इस क्रिया को बादल के निर्माण तथा वर्षा होने से परस्पर संबंधित करें ।
(बादल के बनने तथा वर्षा के होने का कारण-वाष्पन तथा द्रवण)
टिप्पणी: फनल के स्थान पर पानी से भरी कटोरी लेने पर द्रवण बहुत तेजी से होता है ।


जल का वाष्पन एवं द्रवरा

क्रियाकलाप 2

वाष्पन और द्रवण में अंतर स्पष्ट करना

छात्रों को पूर्व ज्ञान है कि भीगे कपड़े वाष्पन के कारण सूखते हैं । उन्हें यह भी ज्ञान है कि गरम करने से वाष्पन शीघ्रता से होता है । पवन पानी के वाष्पन को तेज करने में सहायक है । निम्नलिखित प्रश्नों की सहायता से छात्रों के अनुभव का उन्हें स्मरण कराइए ।

जल का वाष्पीकरण

पूछिए:

क्या होता है जब भीगे कपड़े कुछ समय के लिए खुली हवा में रखे जाते हैं?

भीगे कपड़ों का पानी कहाँ चला जाता है?

पानी किस प्रकार लुप्त हो जाता है?

यह समझने में छात्रों की सहायता कीजिए कि भीगे कपड़ों का पानी वाष्प में बदल जाता है । इस प्रकार से बनी जल वाष्प वायु में मिल जाती है ।

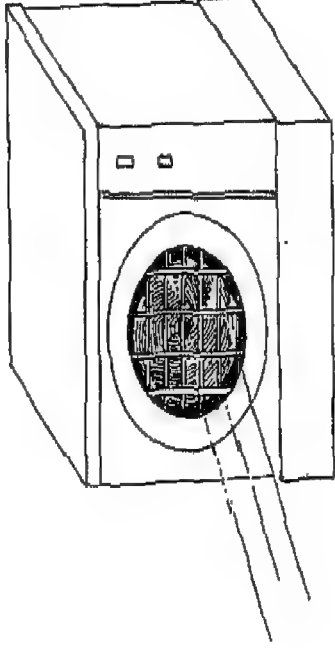
पूछिए:

तुम पानी के वाष्प में बदलने की प्रक्रिया को क्या कहते हो? (वाष्पन)

छात्र अपनी पिछली कक्षा में क्रियाकलाप 4.2.1 में पानी का वाष्पन तथा पानी के वाष्प के द्रवण को प्रदर्शित करने वाला प्रयोग देख चुके हैं । उन्हें इससे संबंधित प्रेक्षणों का निम्नलिखित प्रश्नों द्वारा स्मरण कराइए ।

जल वाष्प ठंडी करने पर क्या होता है?

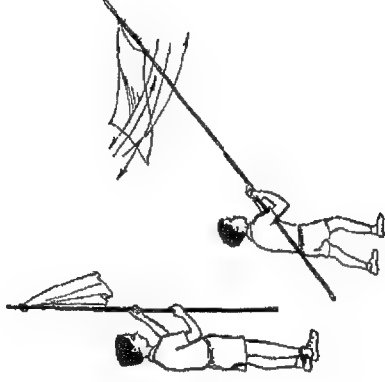
तुम जल वाष्प को जल में बदलने की प्रक्रिया को क्या कहते हो?

वाष्पन और द्रवण में क्या अंतर है?

जल शीतलक

**4.3: वाष्पन दर को प्रभावित करने वाले कारक क्या हैं?**

केंद्रित करें: वाष्पन दर को प्रभावित करने वाले विभिन्न कारण

(कालांश 3)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| | क्रियाकलाप 1 | |
| वायु प्रवाह होने तथा न होने की दशा में वाष्पन दर की तुलना कराना | पतले कपड़े के दो टुकड़ों को पानी में डुबोकर निचोड़ लीजिए। किसी छात्र से कहिए कि एक टुकड़े के दो किनारों को एक बांस के डंडे में बांधकर सूखने के लिए छोड़े। किसी दूसरे छात्र से कहिए कि दूसरे टुकड़े को उसके दो किनारों को बांस के दूसरे डंडे में बांध कर दांए-बांए अथवा ऊपर-नीचे हिलाता रहे।<br>कक्षा के सभी छात्रों को निर्देश दीजिए कि कपड़े के इन टुकड़ों को 10-12 मिनट तक ध्यान से देखते रहें।<br>पूछिए:<br>कपड़े का कौन-सा टुकड़ा अपेक्षाकृत अधिक सूखा है?<br>कपड़े का यह टुकड़ा तेजी से क्यों सूखता है?<br>वायु प्रवाह का वाष्पन दर पर क्या प्रभाव पड़ता है? | पतले कपड़े के दो टुकड़े, बॉंस का डंडा |

वायु प्रवाह वाष्पन में सहायक होता है

यह निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि वायु प्रवाह (पवन) होने पर वाष्पन दर बढ़ जाती है। छात्रों का ध्यान इस तथ्य की ओर आकर्षित कीजिए कि धोबी इस तथ्य का उपयोग भीगे कपड़ों को, विशेषकर साड़ियों को, सुखाने में करता है।

क्रियाकलाप 2

ठंडे और गरम दिन में वाष्पन दर की तुलना करना

दो कटोरियां. अथवा धातु की तश्तरियाँ/प्लेट, चम्मच, जल

धातु की दो कटोरियां अथवा दो तश्तरियां लीजिए। प्रत्येक तश्तरी पर एक-एक चम्मच पानी डालिए। किसी एक छात्र से एक कटोरी तश्तरी को धूप में और दूसरी कटोरी/तश्तरी को छाया में अथवा कक्षा में रखने को कहिए। लगभग एक घंटे बाद छात्रों से कहिए कि इन कटोरियों/तश्तरियां तथा इनमें बचे पानी की मात्रा को ध्यान से देखें।

पूछिए:

किस कटोरी/तश्तरी में अधिक पानी है?

धूप में रखी कटोरी/तश्तरी पर पानी का क्या हुआ?

किस कटोरी/तश्तरी से पानी का वाष्पन अधिक हुआ?

किस दशा में वाष्पन दर अधिक है?

कौन-सा स्थान (धूप अथवा कक्षा) अधिक गर्म है?

दिन की गरमी का वाष्पन दर पर क्या प्रभाव पड़ता है?

किस ऋतु में वाष्पन दर अधिक होती है?

छात्रों को इस तथ्य से अवगत कराइए कि ठण्डे दिनों की अपेक्षा गर्म दिनों में वाष्पन दर अधिक होती है

क्रियाकलाप 3

द्रव की खुली सतह का क्षेत्रफल अधिक और कम होने की दशा में द्रव वाष्पन दर की तुलना कराना

एक ही प्रकार के पतले कपड़े के दो टुकड़े।

एक ही प्रकार के पतले कपड़े के दो टुकड़े लीजिए। उन्हें पानी में डुबाकर एक साथ निचोड़िये ताकि टुकड़े समान रूप से भीग जाएँ। कपड़े के एक टुकड़े की शिकन (झुरियां) झटका देकर दूर कीजिए। कपड़े के एक टुकड़े में तह लगा दीजिए। किसी एक छात्र से कहिए कि तह लगे इस कपड़े के टुकड़े को सूखने के लिए धूप में रखे। दूसरे छात्र से कहिए कि बिना तह लगे कपड़े को धूप में तह लगे कपड़े के टुकड़े के समीप रखें।

छात्रों को बता दीजिए कि कपड़े के इन दो टुकड़ों की आगे की जांच का कार्य आधे घंटे के बाद किया जाएगा। इस अवधि में छात्रों को अन्य क्रियाकलापों में लगाए रखिए। एक छात्र से कहिए कि आधे घंटे के पश्चात् कपड़े के दोनों टुकड़ों को कक्षा में लाए और सभी छात्र इन कपड़ों को छूकर देखें।

विस्तृत सतह वाष्पन में सहायक होती है

पूछिए:

कपड़े का कौन-सा टुकड़ा अधिक सूखा है?

कपड़े के इन टुकड़ों के पानी का क्या हुआ?

कपड़े के किस टुकड़े से पानी का अधिक वाष्पन हुआ है?

कपड़े के किस टुकड़े की खुली सतह का क्षेत्रफल अधिक है?

जल के वाष्पन की दर खुली सतह के क्षेत्रफल पर किस प्रकार निर्भर करती है?

यह निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि पानी की खुली सतह का क्षेत्रफल अधिक होने पर जल का वाष्पन तेजी से होता है। जल अथवा द्रवों से वाष्पन उनके खुली सतह के क्षेत्रफल को कम करके कम किया जा सकता है। दैनिक जीवन के उदाहरणों जैसे-कपड़ों का सूखना, खोया बनाने के लिए दूध को छिछले बर्तन में उबालना, द्रवों को पतले मुँह की बोतल में रखना, आदि से उपर्युक्त अभिधारणा (संकल्पना) को दृढ़ता प्रदान कीजिए।

क्रियाकलाप 4

शुष्क और वर्षा के दिनों में वाष्पन दर का तुलनात्मक ज्ञान देना

निम्नलिखित प्रश्नों की सहायता से विभिन्न ऋतुओं में भीगे कपड़ों के सूखने से संबंधित छात्रों को उनके अनुभव का स्मरण दिलाइए।

एक वर्ष में कितनी ऋतुएं होती हैं?

किस ऋतु में भीगे कपड़े अधिकतम समय में सूखते हैं?
किस ऋतु में भीगे कपड़े तेजी से सूखते हैं?
किस ऋतु में पानी की वाष्पन दर अधिक हो जाती है?
वर्ष में कौन-सी ऋतु सबसे अधिक नम होती है?
वाष्पन दर ऋतु परिवर्तन पर किस प्रकार निर्भर है?
यह तथ्य प्रकाश में लाने में छात्रों की सहायता कीजिए कि पानी का वाष्पन वर्षा के दिन की अपेक्षा शुष्क दिन में अधिक होता है। यही कारण है कि भीगे कपड़े वर्षा ऋतु की अपेक्षा ग्रीष्म ऋतु में कम समय में सूखते हैं।

शुष्क दिन में भीगे कपड़े तेजी से सूखते हैं और वर्षा के दिन सूखने में अधिक समय लेते हैं। वर्षा ऋतु में ग्रीष्म ऋतु की अपेक्षा भीगे कपड़े बहुत देर में सूखते है। वर्षा ऋतु में ग्रीष्म ऋतु की अपेक्षा दिन में वर्षा होने की सम्भावना भी अधिक होती है। वर्षा वाले दिन वायु में जल वाष्प की मात्रा अधिक हो जाती है। परिणामस्वरूप वायु की आर्द्रता बढ़ जाती है जिससे वाष्पन कम हो जाता है।

**4.4: जल वाष्प पर ठंडा करने का क्या प्रभाव पड़ता है और इससे मौसम किस प्रकार प्रभावित होता है?**

**केंद्रित करें: जल वाष्प तथा मौसम पर ठंड बढ़ने का प्रभाव**

(कालांश 3)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| | क्रियाकलाप 1 | |
| जल वाष्प पर ठंड बढ़ने के प्रभाव की पहचान कराना | छात्रों को वाष्पन और द्रवण का पूर्व ज्ञान है। छात्रों से कहिए कि अपने अनुभवों के आधार पर निम्नलिखित प्रश्नों के उत्तर दें:<br>जल के उबलने पर क्या निकलता है?<br>(भाप)<br>तुम क्या देखते हो जब जल वाष्प ठंडी वस्तुओं के सम्पर्क में आती है?<br>(पानी की बूंदों का बनना)<br>यह निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि ठंडी करने पर जल वाष्प जल की बूंदें में बदल जाती है। जल की बूंदें और अधिक ठंडी करने पर बर्फ में बदल जाती हैं। | |

क्रियाकलाप 2

वायुमंडल में जल वाष्प के विभिन्न प्रकार के द्रवण से परिचित कराना

किसी छात्र से कहिए कि एक साफ कटोरी लेकर उसमें उसके आधे भाग तक ठंडा जल भरें। कक्षा के छात्रों से कहिए कि कटोरी की बाहरी सतह को 5-10 मिनट तक ध्यान से देखते रहें।

कटोरी, जल, बर्फ

पूछिए:

कटोरी की बाहरी सतह पर तुम क्या देखते हो?

(जल की बूंदें)

पानी की बूंदों के बनने का क्या कारण है? (वायु में विद्यमान वाष्पकणों का द्रवण)

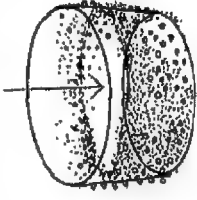
छात्रों से कहिए कि अपने अनुभवों के आधार पर निम्नलिखित प्रश्नों के उत्तर दें:

पानी की छोटी-छोटी बूंदें घास अथवा हरी पत्तियों पर कब दिखाई देती है? (अधिकांशतः शीत ऋतु में प्रातः)

द्रवण क्यों होता है? (वायु में जल वाष्प के ठंडा होने के कारण)

यह समझने के लिए छात्रों को प्रोत्साहित कीजिए कि वायु में विद्यमान जल वाष्प का द्रवण विभिन्न प्रकार से होता है।

क्रियाकलाप 3

बादल, वर्षा, ओस, ओला, कुहरा, पाला, हिम, एवं सहिम वृष्टि की रचना के विभिन्न तरीकों की पहचान कराना

छात्रों से कहिए कि अपने अनुभवों के आधार पर निम्नलिखित प्रश्नों के उत्तर दें:

किस ऋतु में प्रातः तुम्हें भूमि के निकट सफेद धुआं जैसा दिखाई देता है, यहाँ तक कि समीप की वस्तुएँ भी साफ-साफ नहीं दिखाई देती है? (शीत ऋतु)

यह धुआं-जैसी वस्तु क्या है? (कुहरा)

छात्रों का ध्यान इस तथ्य की ओर आकर्षित कीजिए कि शीत ऋतु में जब बहुत अधिक ठंडक होती है तब

वायु में विद्यमान जल वाष्प का धूल तथा धुएँ के कणों पर छोटी-छोटी पानी की बूंदों के रूप में द्रवण हो जाता है और भूमि के निकट धुआं-जैसा दिखाई देता है । इस धुएं-जैसी वस्तु को कुहरा कहते है । वास्तव में कुहरा भूमि के निकट बना हुआ बादल होता है । धूप निकलने पर यह लुप्त हो जाता है । छात्रों का ध्यान क्रियाकलाप 4.4.2 की ओर आकर्षित कीजिए, जिसमें कटोरी की बाहरी सतह पर पानी की छोटी-छोटी बूंदें बन जाती है । यह निष्कर्ष निकालने में उनकी सहायता कीजिए कि पानी की ये छोटी-छोटी बूंदें वायु में उपस्थित जल वाष्प के द्रवण के कारण बनती है, जिन्हें ओस कहते हैं ।

वायु में विद्यमान जल वाष्प जब ऊपर उठती है तो वह ठंडी होकर धूल तथा धुएँ के कणों पर द्रवित होकर पानी की छोटी-छोटी बूंदों में बदल जाती हैं ।

ये नन्हीं-नन्हीं पानी की बूंदें एक दूसरे के निकट आकर बादल का रूप धारण कर लेती हैं । बादल में ये नन्हीं नन्हीं बूंदें जब इतनी बड़ी हो जाती हैं कि वे वायु में रूक नहीं पाती तब वर्षा के रूप में गिरने लगती है ।

विस्तार से स्पष्ट कीजिए कि शीत ऋतु में, विशेषकर पहाड़ी क्षेत्रों में जब अकस्मात बहुत अधिक ठंडक पड़ती है तब वायु की ऊपरी परत में विद्यमान जल वाष्प बर्फ के कणों में बदल जाती है और भूमि पर सफेद रवेदार फाहा के रूप में गिरने लगती है । वायु की ऊपरी परत में विद्यमान जल वाष्प के जमने से बने भूमि पर गिरते हुए बर्फ के कणों को हिम कहते हैं ।

कभी-कभी बहुत ठंडक भरी रातों में ओस अथवा जल वाष्प से बना पानी बर्फ में बदल जाता है । इसे पाला कहते हैं ।

जब गिरती हुई वर्षा की बूंदें भूमि पर पहुंचने के पहले बर्फ में बदल जाती है तो उसे सहिम वृष्टि कहते हैं । कभी-कभी अधिक ठंडक में वर्षा की बूंदों का आकार बड़ा होने के पश्चात् वे बर्फ में बदल जाती हैं और तब वे ओलों के रूप में पृथ्वी पर गिरती हैं ।

जल वाष्प का द्रवरा

**4.5: पैदावार पर भारी वर्षा और पाला का क्या प्रभाव पड़ता है?**

केंद्रित करें: पैदावार पर भारी वर्षा तथा पाला के प्रभाव का परिणाम

(कालांश 1)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| | क्रियाकलाप 1 | |
| खड़ी फसलों पर भारी वर्षा के प्रभाव की पहचाने कराना | छात्रों को उनके अनुभव का स्मरण दिलाइए तथा प्रश्न पूछिए:<br>भारी वर्षा होने पर क्या होता है? (तालाब, गढढे तथा नदियाँ पानी से भर जाती हैं)<br>कुछ दिनों तक लगातार भारी वर्षा होते रहने पर खेतों की खड़ी फसल (पैदावार) पर क्या प्रभाव पड़ता है?<br>(फसल पानी में डूब जाती है)<br>क्या खेतों का पानी लुप्त हो जाता है? (नहीं)<br>खेतों में एकत्रित वर्षा का पानी खड़ी फसल को किस प्रकार प्रभावित करता है? (फसल क्षति ग्रहत हो जाती है)<br>यह निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि लगातार बहुत वर्षा होने से खेतों में बहुत अधिक मात्रा में पानी एकत्रित हो जाता है। मिट्टी कीचड़ में बदल जाती है तथा यह और अधिक पानी सोखने में असमर्थ हो जाती है। पौधों को संभालने की इसकी क्षमता भी समाप्त हो जाती है जिसके परिणामस्वरूप पौधे गिर जाते हैं और फसल क्षतिग्रस्त हो जाती है। | |
| | क्रियाकलाप 2 | |
| खड़ी फसल पर पाला के प्रभाव की पहचान कराना | छात्रों को समीप के खेत में ले जाइए जहां फसल पाला से प्रभावित है।<br>खेत के पौधों कौ छात्रों को ध्यान से देखने दीजिए।<br>पूछिए:<br>पौधों की पत्तियाँ कैसी दिखाई देती हैं?<br>(मुरझा गई हैं)<br>पौधों की पत्तियों के मुरझाने का क्या कारण है?<br>यह निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि पाला के प्रभाव से पौधों की पत्तियाँ मुरझा जाती हैं। ये पौधे बढ़ नहीं पाते हैं। इसलिए फसल क्षतिग्रस्त हो जाती है। पौधों पर पाला के प्रभाव को कम करने के लिए खेत में पानी भर दिया जाता है। | |

## 4.6: मौसम परिवर्तन का जन साधारण, जन्तुओं तथा पौधों के जीवन पर क्या प्रभाव पड़ता है?

कोंद्रित करें: मौसम का जोवन पर प्रभाव

(कालांश 1)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| मौसम परिवर्तन का जन साधारण, जन्तुओं तथा पौधों के जीवन पर प्रभाव की पहचान कराना | क्रियाकलाप 1<br>विभिन्न प्रकार के मौसम तथा इससे पौधों और जन्तुओं पर होने वाले प्रभावों के संबध में छात्रों को उनके अनुभव का स्मरण कराइए और पूछिए:<br>बहुत ठंडे मौसम में लोग किस प्रकार के कपड़े पहनना पसंद करते हैं?<br>बहुत गरम मौसम में लोग किस प्रकार के कपड़े पहनते हैं?<br>ग्रीष्म ऋतु में लोग पहाडों पर क्यों जाते हैं? (ठंडे मौसम के कारण)<br>किस मौसम में तुम्हें बाहर काम करने में कठिनाई होती है?<br>(बरसाती, तूफ़ानी अथवा बहुत गरम मौसम)<br>बहुत ठंडे मौसम का फसल पर क्या प्रभाव पड़ता है?<br>(अधिकांश फसल क्षतिग्रस्त हो जाती है)<br>किस प्रकार के मौसम में तुम्हें अधिक प्यास लगती है?<br>(गरमी के मौसम में)<br>कौन-से पशु ठंडे मौसम में दिखाई नहीं देते हैं?<br>(साँप, मेंढ़क, छिपकली)<br>छात्रों के अनुभव के आधार पर यह निष्कर्ष निकालने में उनकी सहायता कीजिए कि मौसम के परिवर्तन से हमारा रहन-सहन तथा जन्तुओं और पौधों का जीवन प्रभावित होता है। बदलते मौसम में पशुओं के व्यवहार में तथा पौधों के रूप रंग में विशिष्ट परिवर्तन परिलक्षित होते हैं। फसल, बोआई और कटाई पर भी इसका प्रभाव पड़ता है। बरसाती, तुफ़ानी अथवा बहुत गर्म मौसम में यात्रा करना सुविधाजनक नहीं होता। बरसात के मौसम में कुछ पौधे तेजी से बढते हैं। बहुत ठंडे मौसम में सर्प तथा छिपकली दिखाई नहीं देते हैं। | |

## 4.7: मौसम को निर्धारित करने वाले कारक क्या हैं?

केंद्रित करें: मौसम को निर्धारित करने वाले कारक

(कालांश 1)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| | क्रियाकलाप 1 | |
| मौसम निर्धारिते करने वाले कारकों की पहचान कराना | पूछिए:<br>मौसम को निर्धारित करने वाले कारक क्या हैं?<br>छात्रों से कहिए कि पूर्व ज्ञान के आधार पर अपने दैनिक जीवन के अनुभवों का स्मरण करें तथा यह समझने में उनकी सहायता कीजिए कि वायु में विद्यमान जल वाष्प की मात्रा अधिक हो जाने पर मौसम बदल जाता है। वाष्पन दर कम हो जाती है। फलस्वरूप भीगे कपड़ों के सूखने में अधिक समय लगता है।<br>वायु मंडल में बादल आ जाने से भी मौसम बदल जाता है। पवन की गति से भी मौसम प्रभावित होता है। पवन से जल का वाष्पन तेज हो जाता है।<br>ताप वृद्धि से मौसम गर्म हो जाता है। स्पष्ट कीजिए कि मौसम का निर्धारण वायु में विद्यमान जल वाष्प की मात्रा (आर्द्रता), बादलों, पवन की गति और ताप जैसे कारकों से होता है। | |

# इकाई 5: मृदा और फसलें
## (मृदा और फसलें)

प्रस्तावना

छात्र अपने परिवेश की मृदा और फसलों के बारे में जानते हैं । इस इकाई द्वारा छात्रः

— आस-पास उपजाई जाने वाली फसलों को पहचानने,
— वर्ष के विभिन्न मौसमों में उपजायी जाने वाली फसलों को पहचानने,
— अलग-अलग फसलों को अलग-अलग मात्रा में जल एवं ताप की आवश्यकता होती है, पहचानने,
— फसलों की वृद्धि के लिए आवश्यक वस्तुएँ कौन-कौन सी हैं, यह जानने,
— तीनों प्रकार की मृदा में कौन-कौन सी समानताएँ और विभिन्ताएँ होती है, जानने,
— अच्छी और खराब मृदा में अन्तर, जानने,
— विभिन्न प्रकार के मृदा कण गूंथे जाने पर अलग-अलग प्रकार से जुड़ जाते हैं, पहचानने,
— जल रोकने और निकाल देने की क्षमता के आधार पर चिकनी, दोमट और बलुई मृदा को पहचानने,
— विभिन्न प्रकार की मृदाएँ जल के विभिन्न परिमाण अपने में से जाने देती है, जानने,
— मृदा अपने अन्तर कणीय स्थानों में वायु को धारित किये रहती है, जानने,
— अलग-अलग प्रकार की मृदा वायु का अलग-अलग परिमाण धारित किये रहती है, जानने,
— मृदा चट्टानों के टूटने से बनती है, जानने,
— किसी क्षेत्र में पाए जाने वाले पत्थर बड़ी चट्टान से टूटे हुए टुकड़े हैं, जानने,
— चट्टानों के अपक्षय में आंधी महत्वपूर्ण भूमिका निभाती है, जानने,
— बहता हुआ जल चट्टानों के अपक्षय में महत्त्वपूर्ण भूमिका निभाता है, जानने,
— आंधी, मृदा को एक स्थान से दूसरे स्थान की ओर ले जाती है, जानने,
— मृदा के प्रकार एवं उपजाई जाने वाली फसलों के बीच सम्बन्ध को, जानने,
उन विधियों को, जिनसे मृदा उपजाऊ बनाई जा सकती है, पहचानने,
— मृदा में खाद देने और पौधों की वृद्धि में सम्बन्ध को, पहचानने,
— रासायनिक उर्वरक के उपयोग और कृषि उपज के बीच में सम्बन्ध को, जानने,
— फसल चक्र से होने वाले लाभों को जानने,
— अच्छे किस्म के बीज और कृषि-उपज के मध्य सम्बन्ध को, पहचानने,
— कृषि उपज की उचित समय पर सिंचाई किये जाने के प्रभाव को जानने,
— फसलों को बीमारियों से सुरक्षित रखे जाने के उपायों को पहचानने,
— खाद्य अनाजों के संग्रह करने के प्रभावी उपायों को, पहचानने में, समर्थ होंगे ।

**5.1: तुम्हारे क्षेत्र में कौन-कौन सी फसलें उपजाई जाती हैं?**
केंद्रित करें: फसलों के प्रकार

(कालांश 1)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| क्षेत्र में उपजाई जाने वाली फसलों को पहचानना | क्रियाकलाप 1<br>छात्रों को उनके आस-पास के क्षेत्र में ले जाइए और उन्हें खेतों का अवलोकन करने दीजिए। छात्रों से कहिए कि खेत में काम करते हुए व्यक्तियों से साक्षात्कार और वार्तालाप करें।<br>पूछिए:<br>तुमने खेतों में क्या देखा?<br>तुमने खेतों में काम करने वाले व्यक्तियों से क्या-क्या पूछा?<br>छात्रों को बताइए कि उन पौधों को फसल कहते हैं, जो भोज्य पदार्थ प्राप्त करने के लिए खेतों में बोए जाते हैं। कुछ फसलों के नाम बताइए।<br>छात्रों को वर्णन करने दीजिए कि ये फसलें किन क्षेत्रों में उगाई जाती हैं।<br>छात्रों से पूछिए:<br>हम और कौन-कौन-सी फसलें उगाते हैं? | |
| | क्रियाकलाप 2<br>छात्रों से कहिए कि अपने देश के विभिन्न भागों में उपजाई जाने वाली फसलों के चित्र तथा जानकारी, समाचार पत्रों, पत्रिकाओं से एकत्र करके स्क्रैप बुक में चिपकाएं।<br>उनसे रेडियो/टेलीविजन से भी सूचना एकत्रित करने को कहिए। | प्रमुख फसलों के चित्र |

**5.2: विभिन्न ऋतुओं में उपजाई जाने वाली फसलें कौन-कौन-सी हैं?**
केंद्रित करें: मौसमी फसलें

(कालांश 1)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| वर्ष के विभिन्न ऋतुओं में उपजाई जाने वाली फसलों को पहचानना | क्रियाकलाप 1<br>विभिन्न ऋतुओं में उपजाई जाने वाली विभिन्न फसलों का एक चार्ट बनाइए।<br>चार्ट दिखाकर छात्रों से पूछिए: | विभिन्न मौसमों में उपजाई जाने वाली फसलों को प्रदर्शित करने वाला नामांकित चार्ट |

शीत ऋतु के प्रारंभ (अक्तूबर-नवम्बर) में कौन-कौन-सी फसलें उपजाई जाती हैं?
(गेहूँ, चना, मटर, आलू, टमाटर, आदि) ।
ग्रीष्म ऋतु के प्रारंभ (फरवरी-मार्च) में कौन-कौन-सी फसलें उपजाई जाती हैं
(खीरा, ककड़ी, खरबूजा, तरबूज, आदि)
वर्षा ऋतु के प्रारंभ (जून का मध्य) में कौन-कौन-सी फ़सलें उपजाई जाती हैं ।
(धान, मक्का, मिलेट, ज्वार, बाजरा, आदि)
छात्रों को बताइए कि शीत ऋतु के आरंभ में उपजाई जाने वाली फसल को रबी, वर्षा ऋतु के आरंभ में उपजाई जाने वाली फसल को खरीफ तथा ग्रीष्म ऋतु के आरंभ में उपजाई जाने वाली फसल को जायद कहते हैं ।

क्रियाकलाप 2

जानना कि अलग-अलग फसलों को अलग-अलग मात्रा में जल एवं ऊष्मा की आवश्यकता होती है

मौसमी परिस्थितियों के संबंध में छात्रों के पूर्व ज्ञान का स्मरण कराइए और पृथ्वी पर जीवन के लिए इनके महत्व की ओर उनका ध्यान आकर्षित कीजिए ।
पूछिए —
अलग-अलग फसलों को वर्ष के अलग-अलग मौसमों में क्यों उगाया जाता है?
(क्योंकि अलग-अलग फसलों के लिए अलग-अलग मात्रा में जल एवं गर्मी की आवश्यकता होती है तथा अन्य जलवायु-विषयक शर्तें भी भिन्न-भिन्न होती हैं ।

विस्तारण 1

फसलों तथा ऋतुओं, जिनमें वे उपजाई जाती है, के नामों को सूचीबद्ध कीजिए ।

| फसलों के नाम | ऋतुओं का नाम जिसमें वे बोई जाती हैं |
|---|---|
| गेहूं | शीत |
| खीरा/ककड़ी | ग्रीष्म |
| धान | वर्षा |
| — — — | — — — |
| — — — | — — — |

**5.3: फसलों की स्वस्थ वृद्धि के लिए कौन-कौन से कारक आवश्यक होते हैं?**

कोंद्रित करें: फसलों की वृद्धि के लिए आवश्यक परिस्थितियां

(कालांश 2)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| पौधों की स्वस्थ वृद्धि के लिए आवश्यक कारकों को पहचानना | क्रियाकलाप 1<br>छात्रों को क, ख, ग, घ, च, पांच समूहों में बाटिए। प्रत्येक समूह को दो मिट्टी के पात्र/टिन के खाली डिब्बे/छोटे पॉलीथीन के थैले दीजिए। उन्हें अपने पात्र पर क 1, क 2, ख 1, ख 2, ग 1, ग 2, घ 1, घ 2, च 1, च 2 के लेबिल चिपका कर नामांकित करने को कहिए। प्रथम चार समूहों (क, ख, ग, घ) के दोनों पात्रों को स्थानीय मृदा से भरने को कहिए। अन्तिम समूह (च) को एक पात्र (च 1,) को स्थानीय मृदा से दूसरा पात्र (च 2) को बालू से भरने को कहिए। क, ख, ग, च, के समूह के छात्रों को दोनों पात्रों में स्वस्थ, उत्तम (सुधरे) किस्म के बीज बोने को कहिए तथा 'घ' समूक के छात्रों को पात्र (घ1,) में स्वस्थ, उत्तम एवं सुधरे बीज तथा पात्र (घ 2) में खराब किस्म के बीज बोने के लिए कहिए। सभी छात्रों को पात्र (क1) की सिंचाई नियमित रूप से करने एवं पात्र (क 2) की सिंचाई न करने के लिए कहिए। शेष सभी समूहों को अपने पात्रों की नियमित सिंचाई करते रहने दीजिए।<br>समूह (ख) के छात्रों को पात्र ख 1 एवं 2 को खिड़की के पास कमरे में रखने के लिए कहिए। पात्र (ख 1) को खुला रखें तथा पात्र (ख 2) को बड़े पॉलिथीन थैले में रखकर मुँह को डोरी से कस कर बाँधने के लिए कीजिए।<br>समूह ग के छात्रों को (ग 1) को धूप में और पात्र (ग 2)को कमरे के अंधेरे कोने में रखने के लिए कहिए।<br>समूह घ के छात्रों को दोनों पात्र (घ 1) एवं (घ 2) के प्रकाश में रखने के लिए कहिए।<br>समूह च के छात्रों को पात्र (च 1) एवं (च 2) को खुली हवा तथा धूप में रखने को कहिए।<br>सभी समूहों को दो-तीन दिन के पश्चात् पात्रों में हुए परिवर्तनों को नोट करने को कहिए।<br>प्रत्येक समूह द्वारा अवलोकनों को प्रस्तुत करने दीजिए। परिचर्चा के पश्चात् छात्रों से कहिए कि निम्नलिखित सारणी भरें और निष्कर्ष निकालें।<br><br>चिन्ह(✓) उपलब्ध कारक के लिए तथा चिन्ह (X) अनुपलब्ध कारक के लिए उपयोग कीजिए।<br>टिप्पणी: आपके ज्ञान बर्द्धन के लिए सारणी भर दी गई है। | मिट्टी के दस पात्र/टिन के खाली डिब्बे/पालिथीन की थैलियाँ, मृदा, बालू, बड़ी पालिथीन की थैली, बीज |

## अंकुरण को प्रभावित करने वाले कारक

| पात्र का नाम | मृदा | स्वस्थ उत्तम एवं सुधरे बीज | अंकुरण के पश्चात् सिंचाई | खुली वायु | धूप | अवलोकन | कारण |
|---|---|---|---|---|---|---|---|
| $क_1$ | ✓ | ✓ | ✓ | ✓ | ✓ | स्वस्थ | — |
| $क_2$ | ✓ | ✓ | × | ✓ | ✓ | सूख गया | सिंचाई की कमी |
| $ख_1$ | ✓ | ✓ | ✓ | ✓ | ✓ | स्वस्थ | — |
| $ख_2$ | ✓ | ✓ | ✓ | × | ✓ | सूख गया | वायु की कमी |
| $ग_1$ | ✓ | ✓ | ✓ | ✓ | ✓ | स्वस्थ | — |
| $ग_2$ | ✓ | ✓ | ✓ | ✓ | × | पीला और कमजोर | प्रकाश की कमी |
| $घ_1$ | ✓ | ✓ | ✓ | ✓ | ✓ | स्वस्थ | — |
| $घ_2$ | ✓ | × | ✓ | ✓ | ✓ | कमजोर और छोटा | कमजोर बीज |
| $च_1$ | ✓ | ✓ | ✓ | ✓ | ✓ | स्वस्थ | — |
| $च_2$ | × | ✓ | ✓ | ✓ | ✓ | कमजोर एवं छोटा | पोषण की कमी |

छात्रों से पूछिए:

पात्र (क2) के पौधे क्यों सूख गए?

(जल उपलब्ध न होने के कारण)

पालीथीन में बन्द पात्र (ख2) के पौधों की पत्तियाँ क्यों सूख गईं?

(वायु उपलब्ध न होने के कारण)

पात्र (ग2) के पौधों की पत्तियाँ क्यों पीली पड़ गईं?

(प्रकाश उपलब्ध न होने के कारण)

पात्र (घ2) के पौधे कमजोर क्यों दिखाई देते हैं?

(बीजों के उत्तम, स्वस्थ एवं सुधरे न होने के कारण)

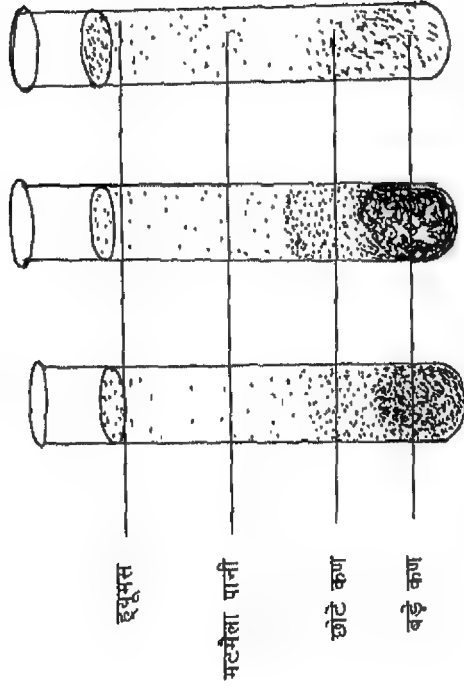
पात्र (च2) के पौधे समुचित वृद्धि क्यों नहीं प्रदर्शित करते हैं?

(अच्छी मृदा अनुपलब्ध होने के कारण)।

यह निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि फसल की वृद्धि के लिए जल, वायु, धूप (सूर्य का प्रकाश), उत्तम बीज एवं उपजाऊ मृदा आवश्यक कारक हैं।

**5.4: विभिन्न प्रकार की मृदा में क्या-क्या समानताएँ तथा विभिन्नताएँ होती हैं?**
**केंद्रित करें: मृदाओं की तुलना**

(कालांश 1-2)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| | क्रियाकलाप 1 | |
| तीनों प्रकार की मृदाओं में समानता को जानना | छात्रों से कहिए कि बलुई, चिकनी तथा दोमट मृदाएँ लाएं।<br>छात्रों से कहिए कि तीन परखनलियों में तीनों प्रकार की मृदाओं को समान परिमाण में मिलाएँ और समान परिमाण में जल भरें। उनसे कहिए कि परखनलियों को एक सलाई द्वारा विलोड़ित करें।<br>परखनली को कुछ समय तक स्थिर रखवा कर कणों की गति का अवलोकन करें।<br>पूछिए:<br>कौन-से कण सर्वप्रथम तली में बैठते हैं?<br>कौन-से कण उस के बाद बैठते हैं?<br>बैठे कणों के ऊपर तुम क्या देखते हो?<br>जल में सबसे ऊपर क्या है?<br>छात्रों से कहिए कि परखनली की वस्तुओं के, अवलोकन के अनुसार चित्र बनाएँ।<br>प्रत्येक नमूने के चारों स्तरों पर परिचर्चा कीजिए और उन्हें बताइए कि सबसे नीचे के स्तर में बड़े कण बालू के हैं, दूसरा स्तर महीन कणों का है जो चिकनी मिट्टी कहलाती है, तीसरा स्तर गँदला जल का है तथा चौथा और सबसे ऊपर का स्तर ह्यूमस का है।<br>पूछिए:<br>तीनों प्रकार की मृदा में बनने वाले चार स्तरों में क्या समानताएँ हैं?<br>यह निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि सभी प्रकार की मृदा जल में चार स्तर बनाती है: बालू, मिट्टी, मटमैला/गँदला जल और ह्यूमस।<br>पूछिए:<br>तीनों प्रकार की मृदा के बनने संबंधी और कौन-सी समानता है?<br>(सभी प्रकार की मृदा चट्टानों के टूटने से बनती है) | तीन परखनलियाँ, एक छोटी सलाई, तीनों प्रकार की मृदा, जल |

क्रियाकलाप 2

तीनो प्रकार की मृदा में अन्तर को जानना

अलग-अलग स्थानों की मृदा, लेन्स

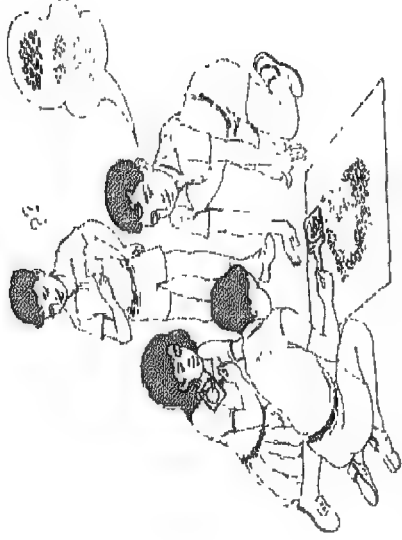
छात्रों को क, ख, ग, तीन समूहों में विभाजित कीजिए । प्रथम समूह (क) से नदी के किनारे अथवा ऊसर भूमि से मृदा मंगवाएँ। द्वितीय समूह (ख) को वाटिका अथवा खेत से मृदा लाने को कहिए । समूह (ग) को तालाब अथवा धान के खेत अथवा, कुम्हार के यहाँ से मृदा लाने के लिए कहिए ।

प्रत्येक समूह के छात्रों से निम्नलिखित अवलोकन कराइए ।

(अ) मृदा का रंग (ब) कणों का आकार (उंगलियों से छूकर तथा लेन्स से देखकर)

छात्रों से कहिए कि मृदा को अपने अंगूठे ओर मध्यमा द्वारा छोटे कणों में मसलें ।

अब उनसे कहिए कि इस ढीली मृदा के कणों के आकार को लेन्स द्वारा देखें तथा छूकर भी अनुभव करें ।

यह निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि मृदा में मूलतः दो प्रकार के कण होते हैं-बड़े तथा छोटे ।

मृदा में बड़े और छोटे कण पाये जाते हैं

क्रियाकलाप 3

तीन परखनलियाँ, तीन प्रकार की मृदाएँ, एक छोटी सलाई, जल

छात्रों से कहिए कि तीनों प्रकार की मृदा (बलुई, दोमट और चिकनी) की बराबर मात्रा जो उन्होंने पूर्व क्रियाकलाप 5.4.2 में एकत्रित की थी उसे तीन परखनलियों में, जल की बराबर मात्रा मिलाएँ और सलाई से हिलाकर स्थिर रखें।

छात्रों से पूछिए:-

किस परखनली में तैरती हुई वस्तुएं सबसे कम मात्रा में हैं?

किस परखनली में तैरती हुई वस्तुएं पहले से अधिक मात्रा में हैं?

किस परखनली में तैरती हुई वस्तुएं दूसरे से भी अधिक मात्रा में है?

जल में तैरती हुई वस्तुओं के नाम बताइए?

उपर्युक्त अवलोकन के आधार पर स्पष्ट कीजिए कि तैरती हुई वस्तुएं मृत पोधों तथा जन्तुओं के सड़ने गलने से प्राप्त कार्बनिक अवशेष हैं, जो मृदा में मिल गए हैं। यह सड़ता गलता हुआ पदार्थ की ह्यूमस कहलाता है।

निम्न सारणी को श्यामपट्ट पर बनाइए और छात्रों की सहायता से उर्पुक्त प्रेक्षण के आधार पर भरिए ।
(यह सारणी आपकी सूचना हेतु भरी जा रही है)
छात्रों से कहिए कि इसे अभ्यास पुस्तिका में बनाएं ।

| मृदा के स्रोत | रंग | कणों का आकार | हयूमस की मात्रा | कणों की दृश्यता |
|---|---|---|---|---|
| बंजर भूमि अथवा नदी के किनारे की मृदा | हल्का | बड़ा | बहुत कम | स्पष्ट |
| खेत की मृदा | हल्के एवं गहरे रंग के बीच का | बड़ा तथा छोटा | बहुत अधिक | कम स्पष्ट |
| तालाब की मृदा | गहरा | बहुत छोटा | कम | अस्पष्ट |

यह निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि मृदाएं अपने गुणों में भिन्न होती है, क्योंकि उनमें कार्बनिक अन्तर्वस्तु (हयूमस) असमान मात्रा में होती है ।
मृदा मुख्यतः तीन प्रकार की होती है जिनके मुख्यतः तीन स्रोत हैं ।

| | स्रोत | मृदा के प्रकार |
|---|---|---|
| (क) | नदी अथवा बंजर भूमि की मृदा | बलुई मृदा |
| (ख) | खेत अथवा वाटिका की मृदा | दोमट |
| (ग) | धान के खेत अथवा तालाब की मृदा | चिकनी मृदा |

## 5.5: अच्छी मृदा क्या होती है?
केंद्रित करें: मृदा के गुण

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| अच्छी तथा खराब मृदा में अन्तर जानना | क्रियाकलाप 1<br>छात्रों से कहिए कि खेत/फार्म पर जा कर किसान से बातचीत करें तथा पूछे कि अच्छी मृदा की उत्तमता के क्या कारण हैं? छात्र अच्छी और खराब मृदा के नमूनों को लाएँ। छात्रों से परिचर्चा कीजिए तथा निष्कर्ष निकालिए कि अच्छी मृदा पौधों को जमीन में मजबूती से पकड़े रहती है, अपने अन्दर जल को धारित किए रखती है तथा पोषक तत्व प्रदान करती है। | अच्छी तथा खराब मृदा के नमूने |
| यह पहचानना कि विभिन्न प्रकार के मृदाकण गूंथे जानेपर अलग-अलग प्रकार से जुड़े रहते हैं | क्रियाकलाप2<br>छात्रों से कहिए कि तीनों प्रकार की मृदा को अलग-अलग जल से गूँथें। फिर प्रत्येक की पट्टी अथवा मोटी बत्ती बनाएंऔर उन्हें धीर-धीरे जमीन की सतह से ऊपर उठाएं। "क्या होता है?" अवलोकन करने में उनकी सहायता कीजिए ओर उनसे पूछिएः<br>तुम क्या देखते हो?<br>कौन-सी मृदा पट्टी अथवा मोटी बत्ती उठाते ही तत्काल टूट जाती है?<br>कौन-सी मृदा पट्टी अथवा मोटी बत्ती उठाने पर कुछ समय तक अटूट बनी रहती है?<br>यह निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि चिकनी मृदा अधिक चिपचिपी है, इसलिए टूटती नहीं है जबकि दोमट मृदा ढीली है, इसलिए टूट जाती है। इसी गुण के कारण चिकनी मृदा से खिलौने बनाए जाते हैं। उन्हें समझाइए कि प्रत्येक प्रकार की मृदा में, आपस में चिपक कर जुड़ जाने की अपनी विशिष्ट सीमा होती है। | तीनों प्रकार की मृदाओं का नमूना |
| चिकनी, दोमट और बलुई मृदा को जल को रोकने और क्षमता के आधार पर पहचानना | क्रियाकलाप 3<br>छात्रों से कहिए कि मिट्टी के तीन छोटे छिद्र युक्त पात्र लें और तीनों प्रकार की मृदा बराबर मात्रा में भरें।<br>— प्रत्येक पात्र के नीचे एक जार रखें।<br>— प्रत्येक पात्र में जल की बराबर मात्रा डालें।<br>— सभी पात्रों को दस मिनट तक इसी अवस्था में रहने दें। | मिट्टी के तीन छोटे छिद्रयुक्त पात्र (कुल्हड़), तीन जार, जल, तीन प्रकार की मृदा |

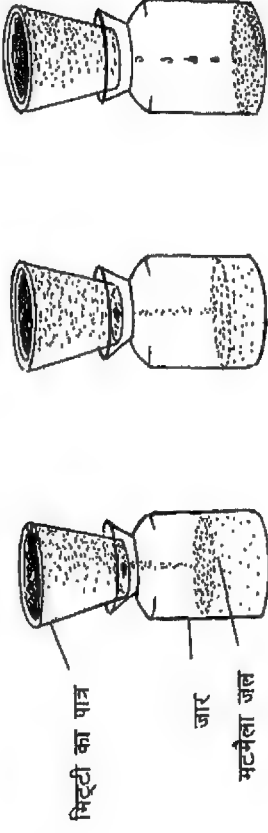
बालू और जल

दोमट और जल

चिकनी मिट्टी और जल

मिट्टी का पात्र

जार

मटमैला जल

तीनों प्रकार की मृदा चिकनी, दोमट, बलुई में कौन अधिक जल संग्रहीत करती है तथा कम जल का निकास करती है। इस के आधार पर इन मृदाओं के नाम उतरते क्रम में अंकित करें।

1. चिकनी
2. दोमट
3. बलुई

क्रियाकलाप 4

जानना कि विभिन्न प्रकार की मृदा अपने अन्दर से जल की अलग-अलग मात्रा को निकल जाने देती है

दो क्वथन परखनलियां, बालू, छोटे कंकड़, जल

छात्रों से कहिए:

दो क्वथन परखनलियां लें। एक में छोटे कंकड़ तथा दूसरी में बारीक बालू भरें।

दोनों परखनलियों में जल की बराबर मात्रा डालें।

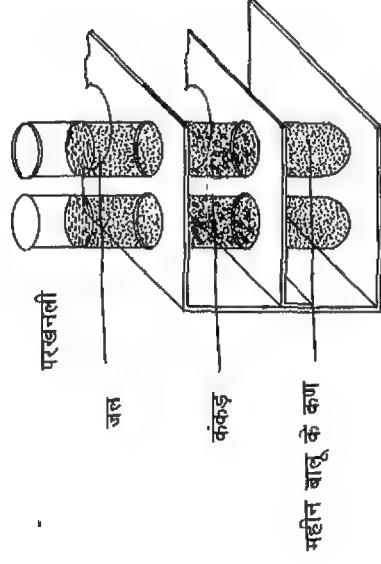
उनसे पूछिए:

किस क्वथन परखनली में अधिक जल तली में हैं?

कंकड से भरी हुई परखनली में बारीक बालू से भरी परखनली की अपेक्षा अधिक जल क्यों है?

छात्रों को बताइए कि:

कंकड़ वाली कवथन परखनली में कंकड़ों के बीच बड़े-बड़े खाली स्थान हैं, जिसके कारण वे अपने में से जल को आसानी से निकल जाने देते हैं। जबकि बालू वाली परखनली में बालू-कणों के पास-पास होने से उनके बीच का स्थान कम होता है, जिसके कारण उनमें से जल कम निकल पाता है। इसी प्रकार बलुई मृदा में

से जिसके कण बड़े हैं, जल शीघ्रता से निकल जाता है। जबकि चिकनी मृदा में से, जिसके कण बारीक हैं, जल शीघ्रता से नहीं निकल पाता है।

विस्तारण1

छात्रों से कहिए कि चिकनी मृदा के खिलौने घर पर बनाएं। छात्रों को बताइए कि चिकनी मृदा का चिपाचिपापन ही खिलौना बनाने में सहायक होता है।

क्रियाकलाप 5

जानना कि मृदा अपने कणों के बीच में वायु धारित किए रहती है

तीन प्रकार की मृदा, तीन परखनलियां, बीकर, जल से भरा पात्र

छात्रों को चार-पांच समूहों में बांटिए। तीन परखनलियों में विभिन्न प्रकार की मृदा भरने को कहिए। छात्रों से कहिए कि परखनली को बड़े पात्र में लिए गए जल में सीधी डुबाएँ और मृदा से निकलने वाले बुलबुलों का अवलोकन करें।

पूछिए:

किस मृदा से बुलबुले तेजी से निकलते हैं?

किस मृदा से बुलबुले देर तक निकलते रहते हैं?

मृदा से वायु क्यों निकल आती है?

तुम्हारे विचार से किस मृदा में अधिक वायु उपस्थित रहती है?

तुम ऐसा क्यों सोचते हो?

यह निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि मृदा के कणों के आकार एवं उसकी वायु धारित करने की क्षमता में संबंध होता है ।

क्रियाकलाप 6

ानना कि अलग-अलग प्रकार की दाओं में वायु धारित करने की मता अलग-अलग होती है

जल से भरा बड़ा पात्र, आठ-दस परखनलियां, जल, तीनों प्रकार की मृदाएं

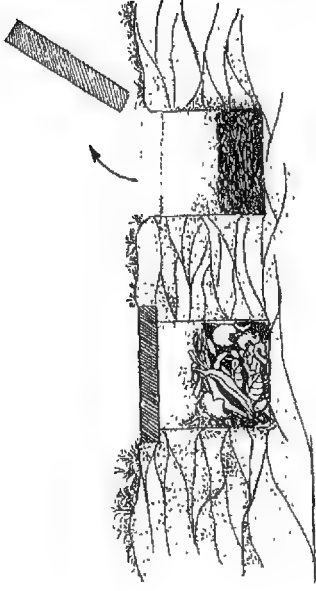
छात्रों को तीन समूहों में बांटिए । पहले समूह को बलुई, दूसरे समूह को चिकनी तथा तीसरे समूह को दोमट मृदा दीजिए । प्रत्येक समूह को दो-दो परखनलियां दीजिए । एक को मृदा से तथा दूसरे को जल से पूरी तरह भरवाइए ।

छात्रों से कहिए कि एक बड़ा पात्र (बाल्टी अथवा कनस्तर) परखनली की लम्बाई से डेढ गुनी अधिक गहराई तक जल से भरें ।

जल से भरी परखनली अंगूठे से बन्द करके जल के अन्दर इस प्रकार उलटवाइए कि परखनली का जल गिरने न पाए और उसका आधे से कुछ अधिक भाग पानी के बाहर निकला रहे । फिर अंगूठे से बन्द करके मृदा से भरी हुई परखनली बाल्टी के जल में शीघ्रता से ले जा कर पहले वाली परखनली के मुंह से सटा देने को कहिए । मृदायुक्त परखनली में जल प्रवेश करेगा और वायु बुलबुलों के रूप में निकल कर पहली परखनली में एकत्रित हो जाएगी, और उतना की जल ऊपर वाली परखनली से नीचे आ जाएगा । जब बुलबुले निकलने बन्द हो जाएं तब ऊपर वाली परखनली में जल के स्तर को चिन्हित करें तथा प्रत्येक समूह को सुझाव दीजिए कि कितना जल परख नली के नीचे की ओर खिसक आता है । प्रत्येक समूह के छात्रों से कहिए कि अपनी परखनली के चिन्हों की तुलना परस्पर करें ।

यह निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि इस विधि द्वारा मृदा में उपस्थित वायु की मात्रा को ज्ञात किया जा सकता है । इससे यह भी प्रमाणित होता है कि बलुई मृदा में सबसे अधिक, तथा चिकनी मृदा में सबसे कम वायु रहती है ।

विस्तारण 1

विद्यालय के मैदान में छात्रों से एक गड्ढ़ा खुदवाइए । इसमें पत्तियाँ, फल-सब्जियों के छिलके आदि गड्ढ़े में डलवाकर एवं मिट्टी से ढकवाकर ऊपर से कुछ जल गिरवाइए । गड्ढे को मिट्टी से बन्द करवाइए । एक माह बाद छात्रों से कहिए कि उसे खोल कर अवलोकन करें ।

कूड़े करकट से भरा हुआ बन्द गड्ढा (पिट)

एक महीने बाद गड्ढा (पिट) खोलने पर प्राप्त हुई खाद

**5.6: तेज वायु (आंधी) और जल किस प्रकार से मृदा के बनने और उसके परिवहन में सहायता करते हैं?**

**केंद्रित करें: मृदा का निर्माण तथा उसका परिवहन**

(कालांश 4-5)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| जानना कि मृदा चट्टानों के टूटने से बनती है | क्रियाकलाप 1<br>छात्रों से कहिए कि आस-पास से विभिन्न प्रकार के पत्थर जैसे, ईंट, संगमरमर, बलुई पत्थर, आदि एकत्रित करें। छात्रों को समूहों में बांट दीजिए और प्रत्येक समूह को किसी एक प्रकार के पत्थर दे दीजिए।<br>उनसे कहिए कि दिये गये पत्थर का रंग और आकार नोट करें।<br>पत्थरों को आपस में अथवा किसी कठोर सतह से छात्रों द्वारा रगड़वाइए तब कहिए कि निकले हुए चूर्ण को एक कागज पर एकत्रित करें। सभी छात्रों द्वारा एकत्रित किए गए चूर्ण को कागज पर मिलाएँ। उनके परिवेश से मृदा का नमूना लाइए और इस चूर्ण से तुलना कीजिए। छात्रों से अवलोकन कराइए कि मिश्रण के कण मृदा के कणों के समान हैं।<br>यह निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि मृदा पत्थरों के कणों और ह्यूमस से मिल कर बनती है। | पत्थरों के नमूने, ईंट, संगमरमर पत्थर, बलुआ पत्थर |

| | | |
|---|---|---|
| | क्रियाकलाप 2 | |
| जानना कि पत्थर बड़ी चट्टान के टुकड़े हैं | एक छात्र से कहिए कि ईंट/बलुआ पत्थर ले और उसे किसी कठोर सतह पर जोर से पटके ताकि वह उस जगह पर बलपूर्वक टकराए। छात्रों से अवलोकन कराते हुए पूछिए:<br>ईंट/बलुआ पत्थर का क्या हुआ?<br>छात्रों को बताइए कि जिस प्रकार से ईंट/बलुआ पत्थर टकराने पर छोटे-छोटे टुकड़ों में टूट जाती है उसी प्रकार उनके आस-पास पाए जाने वाले पत्थर के टुकड़े किसी बड़ी चट्टान के टूटे हुए भाग हैं जो किसी विशेष परिस्थिति में टूट गए हैं।<br>टिप्पणी: छात्रों से कहिए कि इस क्रियाकलाप को सतर्कता पूर्वक करें। | पत्थर, ईंट, बलुआ पत्थर |
| | क्रियाकलाप 3 | |
| जानना कि चट्टान को तोड़ने में आंधी, तेज वायु महत्वपूर्ण भूमिका निभाती हैं | छात्रों को किसी प्राचीन स्मारक, पुराना भवन अथवा मंदिर सैर कराने ले जाइए तथा कहिए कि उसकी दीवार की स्थिति का अवलोकन करें।<br><br>भवन जब बना होगा उस समय भी क्या ऐसा ही रहा होगा जैसा तुम आज देखते हो?<br>ये परिवर्तन किस प्रकार हुए होंगे?<br>छात्रों का ध्यान दीवार पर उगे छोटे पौधों तथा घिसे हुए किनारों की ओर आकर्षित कीजिए। उनसे पूछिए:<br>जब यह पौधे बड़े हो जाएगें तब दीवार का क्या होगा?<br>दीवार के किनारे क्यों घिस गए हैं?<br>छात्रों को बताइए कि भवनों तथा चट्टानों की टूट-फूट को अपक्षय कहते हैं।<br>मौसम के प्रभाव से अपक्षयित पुराने भवनों का सह-संबध पहाड़ों पर चट्टानों के अपक्षय से करने में उनकी सहायता कीजिए। फिर उन मुख्य कारकों का उल्लेख कीजिए जिनसे चट्टानें टूटती हैं, जैसे तेज वायु, वर्षा, सूर्य की किरणों से गर्म एवं ठंडा होने का प्रभाव, पौधों की जड़ों के बढ़ने से पड़ने वाला दाब एवं भूचाल, आदि। | |
| | क्रियाकलाप 4 | |
| जानना कि बहता हुआ जल चट्टानों के टूटने में महत्वपूर्ण भूमिका निभाता है | नदी के किनारे अथवा उसके अन्दर का पत्थर एवं मार्ग के किनारे पड़ा पत्थर छात्रों को दिखाइए।<br>छात्रों से निम्नलिखित प्रश्न पूछ कर उनसे परिचर्चा कीजिए कि बहती नदी किस प्रकार मृदा के निर्माण मे सहायक होती है।<br>नदी के अन्दर अथवा नदी के किनारे का पत्थर गोल और चिकना क्यों होता है?<br>सड़क के किनारे पाया गया पत्थर गोल और चिकना क्यों नहीं होता है? | नदी तथा सड़क के किनारे का पत्थर |

छात्रों को बताइए कि चट्टानों का अपक्षयन केवल पहाडों तक ही सीमित नहीं है बल्कि जब ये बड़े टुकड़े तेज .धार वाली नदियों से नीचे आते है तब ये आपस में रगड़ते हैं एवं जल प्रवाह के प्रभाव के कारण आकार में छोटे और गोल होते जाते हैं । इस प्रक्रिया में जो कण बनते है वे बालू के रूप में बैठते जाते हैं ।

क्रियाकलाप 5

जानना कि तेज वायु (आंधी) मृदा को एक स्थान से दूसरे स्थान की ओर ले जाती है

मृदा चूर्ण, कागज

एक छात्र को कुछ मृदा-चूर्ण एक कागज पर रख कर मुंह से फूंकने के लिए कहिए ।

पूछिएः

मृदा चूर्ण पर तुम्हारे फूंकने का क्या प्रभाव पड़ा?

तुम्हारे आस पास मृदा चूर्ण (धूल) कैसे फैलती है?

यह निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि तेज वायु मृदा कणों को एक स्थान से दूसरे स्थान तक ले जाती है ।

विस्तारण 1

परखनली, बर्फ, नमक, पानी डिब्बा

एक परखनली लीजिए । उसे जल से पूरा भरिए और फिर कार्क द्वारा मजबूती से बन्द कर दीजिए । इस परखनली को टूटे हुए बर्फ और नमक के मिश्रण से भरे हुए डिब्बे में रख दीजिए । इसे रात भर ऐसे ही पड़ा रहने दीजिए और दूसरे दिन छात्रों से अवलोकन करा कर पूछिए ।

गत दिन की अपेक्षा तुम परखनली में क्या परिवर्तन देखते हो?

छात्रों को बताइए कि जब जल, बर्फ में बदलती है तो आयतन के बढ़ने के कारण परखनली को तोड़ देता है । जल के जमने पर प्रसार के कारण परखनली के टूटने की क्रिया का सह-संबंध इसी प्रकार चट्टान के टूटने की क्रिया से स्थापित कीजिए ।

टिप्पणीः साधन उपलब्ध हो तो क्रियाकलाप को कराइए अन्यथा श्याम पट्ट पर समझाइए ।

## 5.7: विभिन्न फसलों के लिए किस प्रकार की मृदा आवश्यक होती है?

**केंद्रित करें: भिन्न भिन्न फसलें भिन्न-भिन्न मृदा में उपजाई जाती है।**

(कालांश 1)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| मृदा एवं फसलों के प्रकार के सम्बन्ध को पहचानना | क्रियाकलाप 1<br>धान, गेंहू, जई के खेत के रंगीन चित्र बनाइए।<br>चित्रों को छात्रों को दिखाकर उनके पूर्व अवलोकनों का स्मरण कराइए।<br>पूछिए:<br>किस फसल को कम जल चाहिए?<br>किस फसल को अधिक जल चाहिए?<br>किस फसल को न कम, न अधिक (सामान्य) जल चाहिए?<br>चार्टों की सहायता लेकर छात्रों से परिचर्चा कीजिए कि धान को चिकनी मिट्टी में उपजाया जाता है और उसकी समुचित वृद्धि के लिए खेतों में थमे हुए जल की आवश्यकता होती है। जब कि गेहूँ को इतनी अधिक मात्रा में जल की आवश्यकता नहीं होती है और वह दोमट मृदा में उपजाया जाता है। जई को वातित (वायुयुक्त) बलुई मृदा में उपजाया जाता है।<br>विस्तारण 1<br>छात्रों से कहिए कि फसलों तथा जिस प्रकार की मृदा में वे उपजाई जाती है सारणी में उसकी सूची तैयार करें। | विभिन्न खेतों में भिन्न-भिन्न फसलों में जल के अलग-अलग स्तरों को दर्शाने वाला चार्ट |

| फसल का नाम | मृदा का प्रकार |
|---|---|
| गेहूं | दोमट |
| धान | चिकनी |
| जई | वातित बलुई |
| तरबूज | बलुई |
| टमाटर | दोमट |
| अन्य सब्जी | दोमट |
| खीरा/ककड़ी | वातित बलुई |
| गन्ना | दोमट |
| मिलेट(ज्वार/बाजरा) | समृद्ध दोमट |

भारत के विभिन्न स्थानों पर विभिन्न फसलों के लिए पाए जाने वाली अनुकूल परिस्थितियों के संबंध में छात्रों से परिचर्चा कीजिए।

**विस्तारण 2**

छात्रों से कहिए कि पॉलिथीन की थैलियों में विभिन्न अनाजों के दानों और उन विभिन्न मृदाओं को जिनमें वे उपजते हैं, अलग-अलग भर कर तैयार करें।

अनाज के दाने और आवश्यक मृदा के युग्मों को आयताकार गत्ते पर नमूने के रूप में लटका दीजिए, जिससे यह प्रदर्शित हो कि फसलें केवल अपने अनुकूल मृदाओं में ही उपजती हैं।

(साधन एवं सामग्री: अनाज के दानों एव उनसे सम्बन्धित मृदा के नमूने)

## 5.8: कौन-कौन-सी विधियों द्वारा मृदा को उपजाऊ बनाया जा सकता है?

केंद्रित करें: मृदा की उर्वरता

(कालांश 3-4)

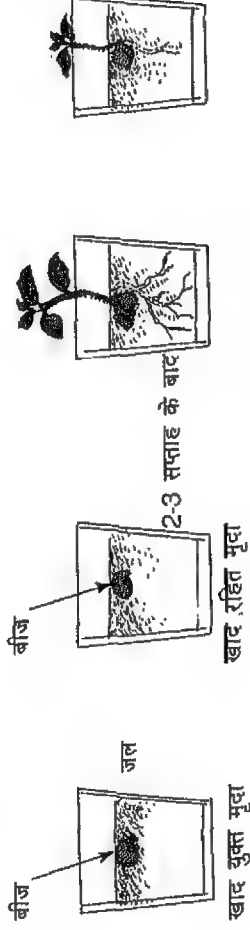
| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| उन विधियों को, जिससे मृदा उपजाऊ बनाई जा सकती है, जानना | क्रियाकलाप 1<br>मृदा की उर्वरता के संबंध में छात्रों के पूर्व ज्ञान का स्मरण कराते हुए उनसे पूछिए:<br>किसान अपने खेत की मृदा को किस प्रकार अधिक उपजाऊ बनाते हैं? (खाद मिलाकर)<br>खाद कैसे बनाई जाती है? (क्रियाकलाप 5.5 विस्तारण-1 का संदर्भ दीजिए)<br>कम्पोस्ट खाद पेड़ों की पत्तियों व टहनियों, फलों एवं सब्जियों के छिलकों के सड़ने से बनती है और गोबर की खाद, पशुओं के गोबर/मल आदि से बनती हैं।<br>पूछिए:<br>मृदा को उपजाऊ बनाने के लिए किसान ओर कौन-कौन सी अन्य खाद उपयोग में लाते हैं?<br>यदि छात्र कोई उत्तर न दे पाएंतब आप उन्हें कुछ रासायनिक उर्वरक, जैसे यूरिया, सुपर फास्फेट, अमोनियम सल्फेट, एन.पी. के., आदि के नाम बता दीजिए।<br>छात्रों को अवगत कराइए कि रसायनिक ऊर्वरक प्रचुर मात्रा में खनिज प्रदान करके मृदा को उपजाऊ (समृद्ध) कर देते हैं, जिससे फसलों की पैदावार बढ़ जाती है। | |

मृदा में खाद देने और पौधों की वृद्धि में संबंध को पहचानना

मिट्टी के दो पात्र, मृदा कम्पोस्ट खाद, चने के बीज, जल

क्रियाकलाप 2

छात्रों से कहिए कि मिट्टी के दो पात्र लें, एक पात्र को आधी मृदा तथा आधी कम्पोस्ट खाद अच्छी तरह से मिलाकर भरें। दूसरे पात्र को बिना खाद मिली समान मात्रा की मृदा से भरे। प्रत्येक पात्र में 4-5 चने के बीज बोएं। पात्रों को दो से तीन सप्ताह तक नियमित रूप से पानी देते रहें। उसके पश्चत् छात्रों से अवलोकन कराकर पूछिए:

मृदा में खाद देना पौधे की वृद्धि में सहायक है

दोनों पात्रों के पौधों की वृद्धि में तुम क्या अन्तर पाते हो?

निष्कर्ष निकालिए कि खाद युक्त मृदा में बोए गए बीज में, खादरहित मृदा में बीज की अपेक्षा तीव्रतर वृद्धि होती है। छात्रों को यह भी बताइए कि मृदा में खाद मिलाने पर पोषक तत्व की मात्रा बढ़ जाती है, और खाद के कारण मृदा अधिक जल धारित कर सकती है, जिससे मृदा की उर्वरता बढ़ जाती है।

रासायनिक उर्वरक के उपयोग और कृषि-उपज के मध्य संबंध को जानना

टमाटर की पौध, रासायनिक उर्वरक

क्रियाकलाप 3

छात्रों से कहिए कि निम्नलिखित कार्य करें।

एक-सी मृदा से टमाटर की पौध के लिए दो क्यारियाँ तैयार करें।

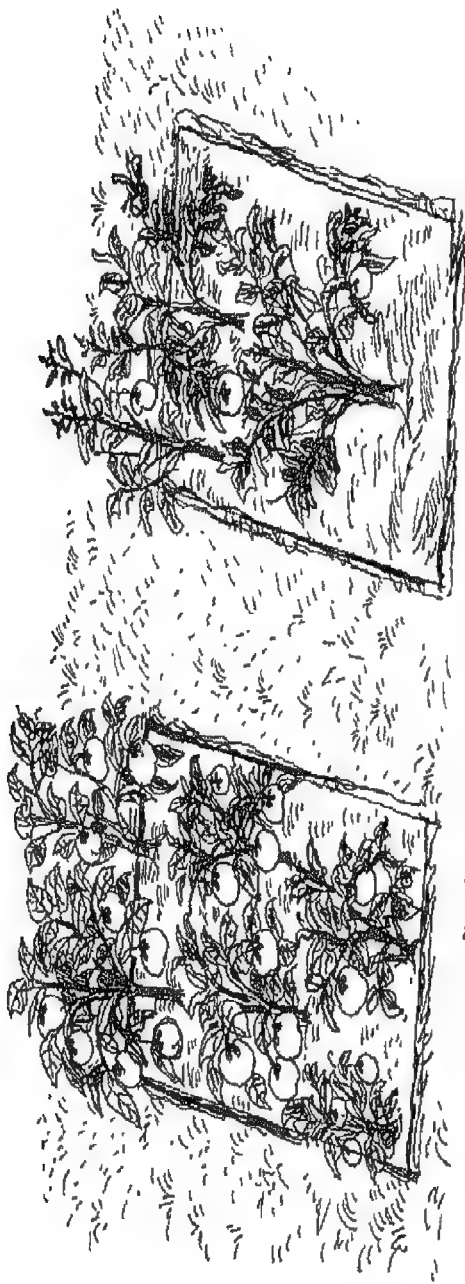
एक क्यारी की मृदा में रासायनिक उर्वरक डालें। दूसरी क्यारी में कोई उर्वरक न डालें। दोनों क्यारियों में टमाटर की पौध लगाएँ। दोनों क्यारियों में फल आने तक प्रतीक्षा करें।

अब छात्रों से पूछिए –

कौन-सी क्यारी अधिक टमाटर देती है?

कौन-सी क्यारी कम टमाटर देती है?

कौन-सी क्यारी बड़े आकार के टमाटर देती है?

कौन-सी क्यारी छोटे आकार के टमाटर देती है?

मृदा में उर्वरक देने से फसल की अच्छी उपज में सहायता मिलती है

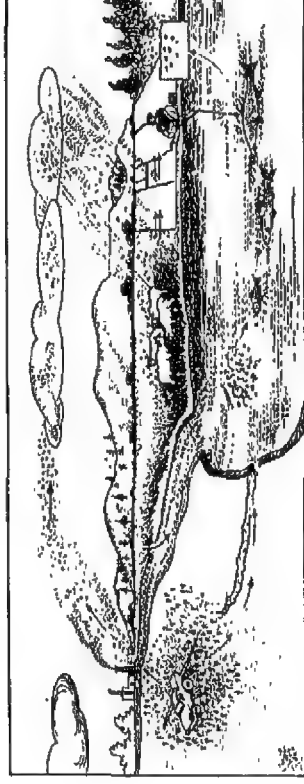
यह निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि उर्वरक-युक्त मृदा द्वारा बड़े आकार और अधिक संख्या में टमाटर प्राप्त हुए हैं । अतः कहा जा सकता है कि कृषि उपज उर्वरक के उपयोग से बढ़ती है । छात्रों को बताइए कि किसान मृदा की आवश्यकता अनुसार रासायनिक उर्वरक का उपयोग अपने खेतों को पोषक तत्वों से समृद्ध बनाने के लिए करते हैं । रासायनिक उर्वरक के विशेष लाभ उन्हें बताइए जैसे कम स्थान घेरना, पौधों को तत्काल पोषक तत्व प्रदान करना आदि ।

टिप्पणीः अधिक मात्रा में रासायनिक उर्वरक का उपयोग पौधों को हानि पहुंचा सकता है ।

क्रियाकलाप 4

छात्रों से कहिए कि अमोनियम सल्फेट, अमोनियम फास्फेट और यूरिया आदि उर्वरकों के नमूने एकत्रित करें । उर्वरकों का एक चार्ट यदि वे इन्हें प्राप्त न कर सकें तब आप इन उर्वरकों को दिखा सकते हैं । विभिन्न उर्वरकों के संबंध में एक चार्ट भी कक्षा में प्रदर्शित किया जा सकता है ।

क्रियाकलाप 5

फसलचक्र से होने वाले लाभों को जानना

छात्रों से कहिए कि अपने क्षेत्र के किसानों से सम्पर्क कर यह जानकारी प्राप्त करें कि वे वर्ष भर में अपनी फसल किस प्रकार उपजाते हैं ।

पूछिए:

गेहूँ की फसल काटने के बाद कृषक कौन-सी फसल उपजाते है?

(गेहूँ की फसल काटने के पश्चात् मूंग, लोबिया, मोठ, उरद आदि फसलें उपजाते हैं)

दालों की फसल काटने के बाद कृषक कौन-सी फसल उपजाते हैं?

(धान, मक्का, ज्वार, बाजरा, तिल, मूंगफली आदि उपजाते हैं)

यदि कृषक उसी फसल को बिना खाद डाले फिर बोता है तो दूसरी बार की कृषि-उपज पहली की अपेक्षा अधिक होगी अथवा कम होगी?

कृषि-उपज में गिरावट क्यों आती है?

गेहूं अथवा धान की फसल काटने के बाद कृषक क्या उपजाते हैं? (विभिन्न प्रकार की फलीदार फसलें)

उर्वरकों का उपयोग करने की अपेक्षा कृषक अल्प-कालीन फलीदार फसलें क्यों उपजाते हैं?

छात्रों को बताइए कि लगातार एक ही फसल बोने से मृदा में नाइट्रोजन यौगिकों की कमी हो जाती है, जिससे कृषि उपज में गिरावट आ जाती है । गेहूं अथवा धान की फसल काटने के बाद फलीदार फसल बोने से मृदा में प्रचुर मात्रा में नाइट्रोजन यौगिक एकत्रित हो जाते हैं, जिससे दूसरी फसल की पैदावार बढ़ जाती है । उन्हें कोई उर्वरक मृदा में नहीं डालना पड़ता और दाल की एक अतिरिक्त फसल भी मिल जाती है ।

इस तथ्य पर बल दीजिए कि फलीदार फसलों को उपजाने से कृषकों को एक अतिरिक्त फसल मिल जाती है तथा अगामी मुख्य फसल के लिए बिना उर्वरक प्रयोग किए मृदा समृद्ध (उर्वर) हो जाती है । इस प्रकार फसल-चक्र से कृषकों को तीन लाभ होते हैः मृदा को उर्वर बनाना, अतिरिक्त फसल प्राप्त होना और उर्वरकों पर होने वाले व्यय को बचाना ।

छात्रों को अनाजों तथा फलीदार पौधों की जड़े दिखाइए। परिचर्चा द्वारा बताइए कि फलीदार पौधों की जड़ों में गांठे होती हैं।

चना, मटर जैसे फलीदार पौधों के जड़ में जो गांठें होती हैं, उनके अन्दर नाइट्रोजन स्थिर करने वाले बैक्टीरिया होते हैं, जो मृदा में नाइट्रोजन की क्षति-पूर्ति कर देते हैं। इसलिये फलीदार पौधों को बोएं जाने से मृदा में नाइट्रोजन की कमी पूरी हो जाती है।

पूछिए:

धान और मक्का की फसल काटने के बाद तुम कौन-सी फसल बोना चाहोगे?

गेहूं की फसल की पैदावार पर क्या प्रभाव पड़ेगा, यदि यह फलीदार पौधों की फसल काटने के बाद उसी खेत में बोई जाएगी।

यह निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि अनाजों और फलीदार पौधों की फसलों के आवर्तन (फसल-चक्र) से मृदा को उर्वर बनाए रखा जा सकता है।

**विस्तारण 1**

-छात्रों से कहिए कि वे कृषकों से सम्पर्क करें और उन फसलों के नाम मालूम करें जो वे लोग धान, गेहूं, मक्का आदि मुख्य फसलों को काटने के बाद उपजाते हैं।

**5.9: बीजों का अच्छा होना (उन्नत बीज) कृषि-उपज की वृद्धि कैसे करता है?**

**केंद्रित करें: उन्नत बीज कृषि उपज बढ़ाते हैं**

(कालांश

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्र |
|---|---|---|
| अच्छे प्रकार के बीज और कृषि-उपज के मध्य संबंध को पहचानना | क्रियाकलाप 1<br>छात्रों से कहिए कि किसानों से सम्पर्क करें और यह पता लगाएं कि किस-किस प्रकार के बीज बोने पर कैसी फसलें होती हैं?<br>पूछिए:<br>उस बीज की किस्म का नाम बताइए जो बोया गया है?<br>किसान उत्तम प्रकार के बीज क्यों बोता है?<br>छात्रों को बताइए कि उन्नत प्रकार के बीज बोने से अधिक पैदावार होती है, पौधों में बीमारी नहीं होती अथवा कम होती है और फसलें कम समय में पक कर तैयार हो जाती हैं। | |

**5.10: सिंचाई किस प्रकार पैदावार की वृद्धि में सहायक है?**
**केंद्रित करें: पैदावार और सिंचाई**

(कालांश 1)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| कृषि-उपज पर उचित समय पर सिंचाई किए जाने के प्रभाव को जानना | क्रियाकलाप 1<br>पूछिए –<br>समुचित वर्षा के अभाव का कृषि उपज पर क्या प्रभाव पड़ता है?<br>समय पर वर्षा के अभाव में होने वाली क्षति को न्यून करने के लिए किसान पूर्व से बोई गई फसल की सुरक्षा के लिए क्या करते हैं? (सिंचाई)<br>निकटवर्ती नहरों से जल लेकर अथवा कुओं से जल निकालकर खेतों की सिंचाई करते हैं ।<br>खेतों में कुएँ क्यों पाये जाते हैं?<br>छात्रों को बताइए कि ये कुएँ उचित समय पर सिंचाई के लिए सहायक होते हैं । आजकल सिंचाई की आधुनिक सुविधाएं जैसे नहर, ट्यूब-वेल आदि का विकास हो गया है, जिससे सिंचाई करने से एक वर्ष में दो या उससे अधिक फसलें उपजाई जा सकती हैं । | |

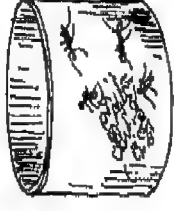
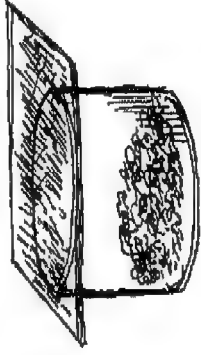
**5.11: कीटों एवं रोगों से फसलों को कैसे सुरक्षित रखते है और कैसे उनका संग्रह किया जाता है?**

**केंद्रित करें: फसल सुरक्षा एवं संरक्षण**

(कालांश 1)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| | क्रियाकलाप 1 | |
| फसलों को, बीमारियों से सुरक्षित रखे जाने के उपायो को पहचानना | कक्षा में परिचर्चा करके छात्रों से पूछिएः<br>रोग एवं कीटों से फसलों को किस प्रकार सुरक्षित रखा जाता है?<br>कुछ कीटनाशक एवं रोग नाशक दवाओं के नाम बताओं? (गैमेक्सीन, मेलाथियान)<br>टिप्पणीः छात्रों को बताइये कि ये कीट नाशक विषैले है अतः इनका उपयोग सावधानी से करना चाहिए।<br>सामान्यतया फसलों को कीटों एवं रोगों से बचाने के लिए कीटनाशक एवं रोग नाशक दवाओं का छिड़काव किया जाता है। | |
| | क्रियाकलाप 2 | |
| अनाजों के संग्रह करने के प्रभावी उपायों को पहचानना। | छात्रों से पूछिएः<br>तुम्हारी माँ घर में अनाज का किस प्रकार संग्रह करती है?<br>वे अनाज को टिन अथवा मिट्टी के पात्रों में क्यों रखती हैं?<br>क्या तुम्हारी माँ लम्बे समय तक परिरक्षण के लिए अनाज में कुछ मिलाती हैं?<br>अनाज को धूप में क्यों फैलाती है और सूखे स्थान में रखती हैं?<br>बड़े-बड़े गोदामों में अनाज किस प्रकार संग्रहित किया जाता है? (फ्यूमिगेशन, कीटनाशक का छिड़काव करके)<br>छात्रों को बताइए कि अनाज को निम्नलिखित उपायों द्वारा प्रभावी ढंग से संग्रहित किया जा सकता है।<br>कीटों एवम् नाशी जन्तुओं जैसे चूहा, दीमक, घुन आदि से नष्ट होने से बचाने के लिए सूखे स्थान, जलरूद्ध, वायुरूद्ध पात्रों में अनाजों को नमी से मुक्त करके रखते हैं। | |

**विस्तारण 1**

छात्रों से कहिए कि दो पात्र लें और दोनों में अनाज रखें। एक पात्र को ढकें तथा दूसरे को खुला रखें। कुछ दिन तक नियमित अवलोकन कर अपने अनुभवों को कक्षा में प्रस्तुत करें।

# इकाई 6: बल, कार्य तथा ऊर्जा

## (कार्य, बल और ऊर्जा)

प्रस्तावना

छात्र उन वस्तुओं से परिचित हैं जो उनके चारों ओर गति कर रही है। वे यह भी जानते है कि धक्का देने अथवा खींचने से वस्तुएँ गतिमान हो सकती हैं।

इस इकाई द्वारा छात्रः

- बल को धकेल अथवा खिंचाव के रूप में परिभाषित करने, तथा वस्तुओं पर इसके प्रभाव को बताने,
- बल लगाने से कार्य तभी होता है, जब वस्तु विस्थापित हो जाय, इस तथ्य से अवगत होने,
- जन्तु एवं मनुष्य अपनी पेशियों द्वारा बल लगाते हैं, जानने,
- कार्य करने के लिए ऊर्जा की आवश्यकता होती है, जानने,
- ऊर्जा के विभिन्न रूपों (उष्मीय, यांत्रिकी तथा विद्युतीय) से परिचित होने,
- ऊर्जा के एक रूप को दूसरे रूप में रूपान्तरित किया जा सकता है, समझने,
- ऊर्जा-संरक्षण की आवश्यकता के महत्व को समझने में, समर्थ होंगे।

**6.1:** बल क्या है?

**केंद्रित करें: बल को धकेल अथवा खिंचाव के रूप में परिभाषित करना**

(कालांश 2-3)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| स्थिर अवस्था में रखी वस्तुओं पर धकेल अथवा खिंचाव के प्रभाव से परिचित कराना | क्रियाकलाप 1<br>छात्रों का ध्यान, विभिन्न वस्तुओं जैसे कुर्सी, पत्थर, किताब, मेज अथवा कक्षा के फर्श पर रखी गेंद की ओर आकर्षित कीजिए। छात्रों से कहिए कि किसी एक वस्तु को एक समय में धकेलें अथवा खींचें।<br>क्या होता है जब तुम किसी वस्तु को धकेलते हो?<br>क्या होता है जब तुम किसी वस्तु को खींचते हो?<br>(धकेलने अथवा खींचने से कुछ वस्तुएं गतिमान हो जाती हैं)<br>किसी वस्तु को गतिशील बनाने के लिये क्या किया जाना चाहिए? | मेज, कुर्सी, पत्थर, किताब, गेंद |

क्रियाकलाप 2

छात्रों से कहिए कि पत्थर, ईंट, लकड़ी का गुटका आदि को रस्सी, अथवा डोरी से बाँधें तथा उन्हें रस्सी की सहायता से खींचे।

पत्थर, ईट, लकड़ी का गुटका, रस्सी

वस्तुओं को रस्सी द्वारा खींचने पर क्या होता है?

क्रियाकलाप 3

धकेल अथवा खिंचाव को बल के रूप में बताना

छात्रों को खेल के मैदान में ले जाइए और उनसे एक ईंट या एक पत्थर उठाने को कहिए तथा उनसे इन वस्तुओं को एक स्थान से दूसरे स्थान तक ले जाने को कहिए।

दैनिक जीवन से पांच उदाहरण बताइए जहां खींचने और धकेलने से वस्तुएँ गतिमान हो जाती हैं। स्पष्ट कीजिए कि वस्तुओं पर लगाए गए धकेल अथवा खिंचाव को बल कहते हैं।

नीचे दी गई परिस्थितियों में धकेल अथवा खिंचाव में से कौन सी परिस्थितियाँ वस्तु में गति उत्पन्न करने के लिए उत्तरदायी है?

खिड़कियों का खोलना, कमरे के दरवाजों को बंद करना, कुएंसे पानी निकालना, गेंद को ठोकर मारना, पानी से भरी बाल्टी को भूमि से ऊपर उठाना, पहिये वाले खिलौने को रस्सी से गतिमान करना, हथौड़े की सहायता से लकड़ी के गुटके में कील ठोकना, आदि

यह विचार विकसित करने के लिये कि पशु भी धकेल अथवा खिंचाव द्वारा बल लगाते हैं, उनसे पूछिए: तांगा कौन खींचता है?

छात्रों से कहिए कि किसी दीवार, भारी मेज तथा भारी पत्थर को धकेले अथवा खीचें।

(छात्र इन भारी वस्तुओं को खिसका नहीं सकेंगे)

उपयुर्क्त भारी वस्तुओं को धकेलने तथा खींचने से क्या होता है?
धकेलने से ईंट तो खिसक जाती है परन्तु भारी पत्थर नहीं खिसकता है, क्यों?
(अधिक बल की आवश्यकता होती है)
यह निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि "खिंचाव" वस्तु को हटा सकता है अथवा नहीं भी। भारी वस्तुओं को हटाने के लिये अधिक धकेल अथवा अधिक खिंचाव की आवश्यकता है। धकेल अथवा खिंचाव में हम बल लगाते हैं।

गतिमान वस्तु पर धकेल अथवा खिंचाव के प्रभाव से परिचित कराना

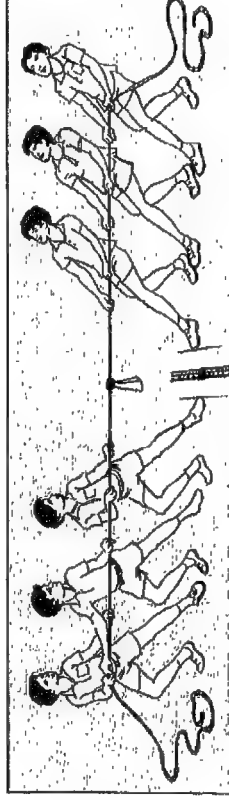
क्रियाकलाप 4

रबर की गेंद, मेज/फर्श

कक्षा में फर्श/मेज पर एक गेंद को लुढकाइए।
छात्रों से कहिए कि इस लुढकती गेंद पर गति की दिशा में एक धक्का या ठोकर लगाएँ।
उनसे पूछिएः
कब गेंद अधिक तेजी से आगे बढ़ी, धक्का देने के पूर्व अथवा धक्का देने के बाद?
जब किसी गतिमान वस्तु को उसकी गति की दिशा में धक्का दिया जाता है तो क्या होता है?
गतिमान गेंद को कैसे अधिक गतिशील बना सकते हैं?
क्या अधिक तेज गति के लिए गेंद पर, उसकी गति की दिशा में ही बल लगाते हैं?
दैनिक जीवन से गति को तेज करने के कुछ उदाहरण दीजिए।
किसी गतिमान गेंद को तुम कैसे रोक सकते हो?
क्या गतिमान गेंद को रोकने के लिए तुम्हें उसकी गति-दिशा के विपरीत दिशा में बल लगाना पड़ता है?
दैनिक जीवन से, गति को धीमा करने के कुछ उदाहरण दीजिए।
छात्रों से क्रिकेट या फुटवाल मैच के बारे में विचार विमर्श कीजिए। उनसे यह निष्कर्ष प्राप्त कीजिए कि गतिमान गेंद भी बल (धक्का) लगा सकती है, तथा उस पर भी बल लगाया जा सकता है। गेंद की गति को उसकी गति की दिशा में बल लगा कर तेज किया जा सकता है तथा विपरीत दिशा में बल लगा कर धीमा किया जा सकता है।

विस्तारण 1
छात्रों को खेल के मैदान में ले जाइए और दो टीम अ एवं ब बना कर रस्साकसी का खेल खेलने को कहिए जिसमें टीमें एक दूसरे को खीचें।

उनसे पूछिए:
कौन-सी टीम जीतती है, अ अथवा ब?
दूसरी टीम क्यों नहीं जीती?
(जीतने वाली टीम दूसरी टीम से खींचने में अधिक बल लगाती है)

जब दोनों में से कोई भी टीम दूसरे को खींच नहीं पाती तब तुम क्या निष्कर्ष निकालेंगें?
(दोनों टीमें समान बल लगाती हैं)

रस्साकसी

**6.2: कार्य कैसे होता है?**

**केंद्रित करें: कार्य तभी होता है जब बल वस्तु को गतिमान कर दे।**

(कालांश 1)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| इस तथ्य से अवगत कराना कि बल लगाने से कार्य तभी होता है जब वस्तु विस्थापित हो जाय | क्रियाकलाप 1<br>ऐसे सभी प्रकार के सम्भव "कार्यों" के बारे में छात्रों से पूछिए जिनके संपर्क में वे दैनिक जीवन में आते हैं। प्रारम्भ में आप कुछ उदाहरण दीजिए जैसे मनुष्य द्वारा किया गया कार्य, मशीन द्वारा किया गया कार्य, पशुओं द्वारा किया गया कार्य, आदि। इन सभी प्रकार के कार्यों की सूची श्यामपट्ट पर बनाइए। छात्रों की सहायता से इन्हें विभिन्न समूह में वर्गीकृत कीजिए। इनमें से एक समूह ऐसा होना चाहिए, जिसके अन्दर | |

धकेल तथा खिंचाव की क्रिया हो ।

छात्रों को बोध कराइए कि जब धकेल अथवा खिचाव से कार्य किया जाता है तब उस दशा में वस्तु पर बल लगाया जाता है ।

क्रियाकलाप 2

छात्रों से कहिए कि कुर्सी, बस्ता, ईंट आदि एक स्थान से दूसरे स्थान तक ले जाएँ।

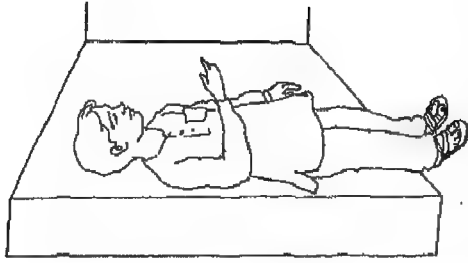
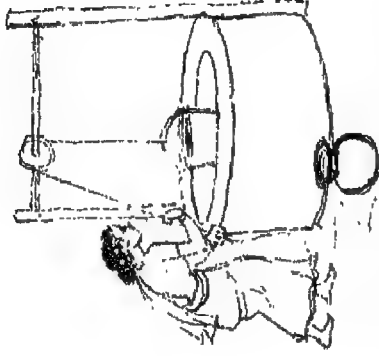
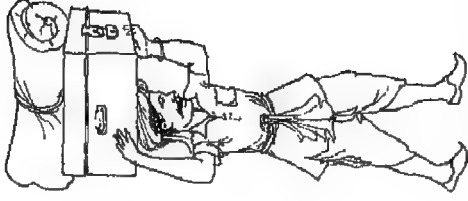
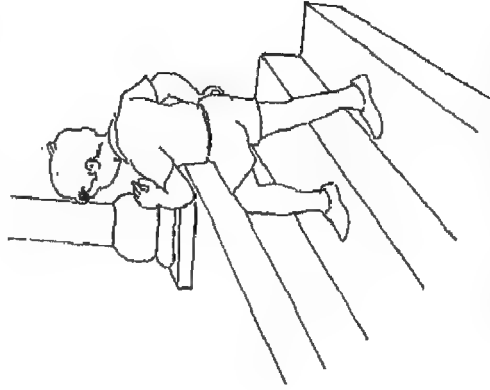
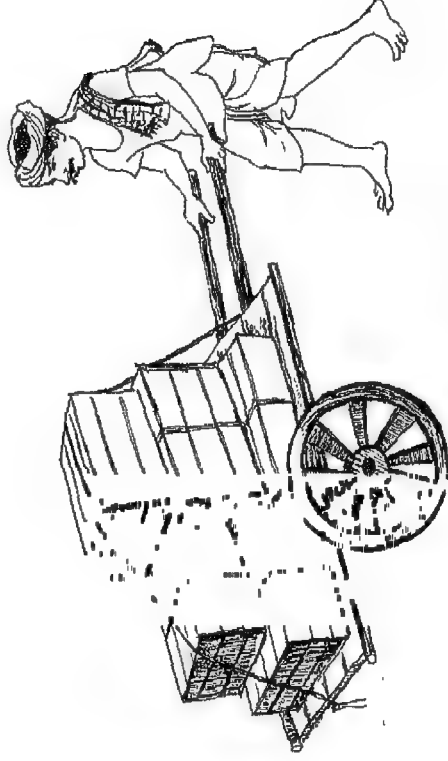
ईंट, कुर्सी, स्कूल बैग (बस्ता)

तुमने कुर्सी/बस्ता/ईंट को एक स्थान से दूसरे स्थान तक हटाने में क्या किया?

इन वस्तुओं पर बल लगाने का क्या प्रभाव हुआ?

क्या तुमने इन वस्तुओं के हटाने में कार्य किया है?

चित्रों में दर्शाई गई अवस्थाओं के अनुसार, जिनमें कार्य होता है, को चुनकर टिक (✓) लगाने को कहिये ।

(अ) दीवार के सहारे खड़ा बालक (✗)
(ब) भारी बकसा ले जाता कुली (✓)
(स) कुएँ से पानी खींचती हुई औरत (✓)
(द) सीढ़ियों पर चढ़ता बालक (✓)
(ग) ठेला/गाड़ी धकेलता हुआ मनुष्य (✓)

दीवार के सहारे खड़ा बालक

कुएँ से पानी निकालती हुई औरत

भारी सन्दूक को उठाता हुआ कुली

सीढ़ी पर चढ़ता हुआ बालक

गाड़ी धकेलता हुआ मनुष्य

**6.3:** हम बल कैसे लगाते हैं?

केंद्रित करें: पेशीय बल

(कालांश 1)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| इस तथ्य से अवगत कराना कि मनुष्य तथा पशु अपनी मांस पेशियों द्वारा बल लगाते हैं | क्रियाकलाप 1<br>छात्रों से कहिए कि कुर्सी, मेज, ईंट आदि वस्तुओं को उठाएँ, अथवा भारी मेज को एक स्थान से दूसरे स्थान तक हटाएँ। छात्रों से पुनः कहिए कि अपने स्कूल बैग अथवा ईंट को एक हाथ से उठाएँ।<br>पूछिए:<br>तुम्हारे शरीर का कौन-सा अंग, वस्तु को खिसकाने तथा उठाने में बल आरोपित करता है?<br>तुम्हारी भुजा के कौन-से भाग में तनाव हो जाता है?<br>छात्रों को मनुष्य की मांस पेशियों के बारे में समझाइए और उन्हें भुजाओं की मांसपेशियों से परिचित कराइए और बताइए कि इन्हीं मांस पेशियों द्वारा बल लगाया जाता है।<br>समझाइए कि पेशीय बल का उपयोग होता है:<br>गेंद को ठोकर मारने, गेंद को बल्ले से मारने, गेंद को फेंकने, मसाला पीसने, कपड़ों को धोने, चीजों को काटने, रिक्शा, बैलगाड़ी, अथवा तांगा को खींचने, गाड़ी के चालन-चक्का (स्टियरिंग व्हील) को घुमाने आदि में।<br>छात्रों से कहिए कि कुछ और ऐसे उदाहरण दें जिसमें पशु अपनी मांस पेशियों द्वारा बल लगाते हैं। | कुर्सी, मेज, स्कूल बैग, ईंट |

**6.4:** कार्य करने के लिये क्या आवश्यक है?

केंद्रित करें:- कार्य करने के लिय ऊर्जा की आवश्यकता होती है।

(कालांश 2-3)

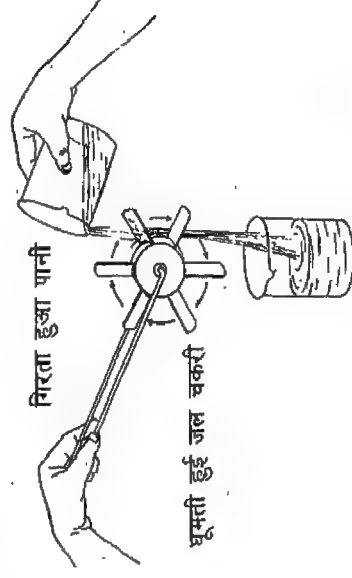
| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| इस तथ्य से परिचित कराना कि कार्य करने के लिये ऊर्जा की आवश्यकता होती है | क्रियाकलाप 1<br>छात्रों का ध्यान कुछ दैनिक जीवन से संबंधित परिस्थितियों की ओर आकर्षित कीजिए।<br>उनसे पूछिए:<br>कार को चलाने के लिए पेट्रोल की आवश्यकता क्यों होती है? | |

गाड़ी को चलाने के लिये कोयले या विद्युत की आवश्यकता क्यों होती है?
घर में पंखा चलाने के लिये विद्युत की आवश्यकता क्यों होती है?
इन परिस्थितियों से निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि जब कार, रेलगाड़ी तथा पंखे चलते हैं तो कुछ खर्च होता है और इन्हें सतत् कार्य करने के लिये कुछ आपूर्ति की आवश्यकता होती है।
कार, रेलगाड़ी तथा पंखा चलाने के लिये ऊर्जा, पैट्रोल, कोयला तथा विद्युत से प्राप्त होती है। यदि इस ऊर्जा की आपूर्ति बंद कर दी जाय तो कार्य करना बन्द कर देती हैं। अतः कार्य करने के लिये ऊर्जा की आवश्यकता होती है।
बैलगाड़ी अथवा तांगा किस के द्वारा आगे बढ़ता है?
(पशुओं से लगाए गए पेशीय बल के द्वारा)
इन पशुओं को ऊर्जा की आवश्यकता होती है, वे ऊर्जा कहाँ से प्राप्त करते हैं?
क्या होता है जब उन्हें पर्याप्त भोजन नहीं मिलता है?
क्या होता है जब तुम्हें पूरे दिन भोजन नहीं मिलता है?
कार्य करने के लिये आवश्यक ऊर्जा कौन देता है?

इस तथ्य से अवगत कराना कि मशीनों को कार्य करने के लिए ऊर्जा की आवश्यकता होती है

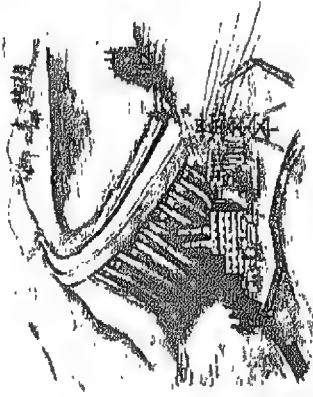
क्रियाकलाप 2

जलचकरी, बीकर, पानी

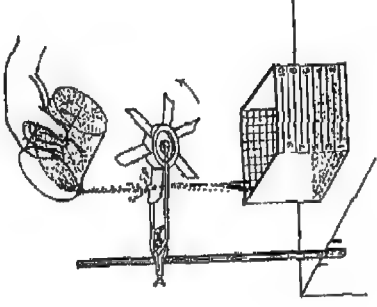
जैसा कि चित्र में दिखाया गया है छात्रों से कहिए कि जल चकरी पर पानी गिराते रहें।
क्या जलचकरी घूमने लगती है?
जलचकरी कैसे गतिमान हुई?



गतिमान पानी, जलचकरी को घुमा देता है

जल विद्युत शक्तिगृह का चार्ट

क्या होता है जब जलचकरी की फलकों पर पानी गिरता है?
ऊर्जा का वह कौन-सा स्रोत है, जो जलचकरी को घुमाता है?
स्पष्ट समझाइए कि गतिमान पानी, ऊर्जा का स्रोत है । इस गतिमान पानी की ऊर्जा से जल विद्युत-शक्ति-गृह के टर्बाइन चलाए जाते हैं ।
इसको चार्ट की सहायता से समझाइए ।

जल विद्युत शक्ति गृह

क्रियाकलाप 3

कागज की बनी फिरकी

छात्रों से कहिए कि कागज की फिरकी बनाएँ तथा उस पर मुंह से हवा फूकें ।
उनसे पूछिएः
क्या होता है जब कागज की फिरकी पर हवा फूकते हैं?
उनमें कुछ छात्रों से कहिए कि कागज की फिरकी को हाथ में उठाकर दौड़ें।
जब फिरकी लेकर दौड़ते हैं तो फिरकी तेज़ी से क्यों घूमनें लगती है?
क्या यह घूमेगी यदि न तो तुम चलो अथा दौड़ों, और न ही हवा बह रही हो?
ऊर्जा का वह क्या स्रोत है जो फिरकी को घुमाता है?
समझाइए कि गतिमान हवा, ऊर्जा का स्रोत है, जिसका उपयोग पवन-चक्की चलाने में किया जाता है।
इस प्रकार के क्रियाकलापों से छात्रों को स्पष्ट अनुभव कराइए कि इस पृथ्वी पर सभी पशुओं तथा सभी मशीनों को कार्य करने के लिये ऊर्जा की आवश्यकता होती है।

पवन-चक्की की कार्यविधि को बताने के लिए चार्ट

**विस्तारण 1**

यदि सम्भव हो तो छात्रों को जल-विद्युत-शक्ति-गृह दिखाने के लिए भ्रमण की व्यवस्था कीजिए और दिखाइए कि गतिमान पानी में, टर्बाइन को चलाने के लिए, ऊर्जा होती हैं।

**6.5: ऊर्जा के विभिन्न रूप क्या हैं?**

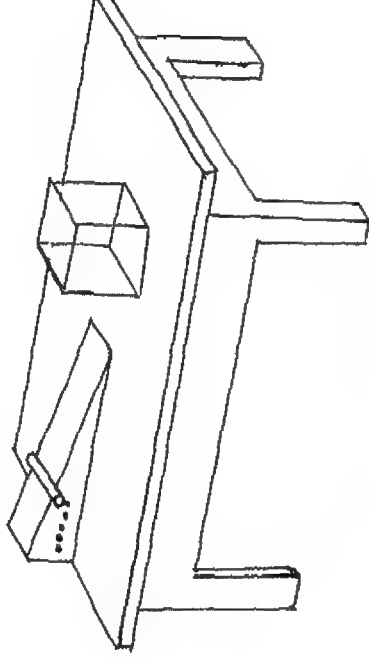
**केंद्रित करें: ऊर्जा के विभिन्न रूप**

(कालांश 5-6)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| | क्रियाकलाप 1 | |
| *यांत्रिक ऊर्जा से परिचित कराना* | छात्रों से कहिए कि एक स्थिर रखी हुई गोली को दूसरी गोली से मारें।<br>क्या होता है जब स्थिर अवस्था में रखी एक गोली को गतिमान गोली से मारते हैं?<br>क्या होता है जब गेंदबाज द्वारा फेंकी गई क्रिकेट की गेंद स्टम्प्स से टकराती है?<br>यह स्पष्ट रूप से समझने में छात्रों की सहायता कीजिए कि उन वस्तुओं में, जो अन्य वस्तुओं को गतिशील बना देती हैं, ऊर्जा होती है।<br>उनसे पर्यावरण *की अन्य स्थितियों के उदाहरण पूछिये जहां पर इस प्रकार की ऊर्जा से कार्य होता है।* उदाहरणार्थ, बहते हुये पानी में कागजकी नाव, बाढ़ के पानी से ले जायी गयी वस्तुएँ, तेज हवा में उड़ती हुई वस्तु, आदि। इन सभी उदाहरणों में गतिमान वस्तुओं के कारण अन्य वस्तुएँ गति करने लगती हैं। गतिमान वस्तुओं में उपस्थित ऊर्जा को यांत्रिक ऊर्जा कहते है। | 2 गोलियां |

क्रियाकलाप 2

जैसा कि चित्र में दिखाया गया है, उसके अनुसार छात्रों से क्रियाकलाप हेतु व्यवस्था करने को कहिए।

मेज धातु का बेलन,

गतिमान वस्तुओं में यांत्रिक ऊर्जा होती है

छात्रों से कहिए कि पच्चर/नतसमतल से धातु के बेलनों को इस प्रकार लुढ़काएँ कि यह घन सेन्टीमीटर ब्लाक से आघात करे।

पूछिए:

तुम क्या देखते हो?

किस वस्तु ने ब्लाक पर बल लगाया, जिसके कारण ब्लाक गतिमान हो गया?

गतिमान धातु के बेलन ने क्या कोई कार्य किया?

गतिमान बेलन में कैसी ऊर्जा होती है?

यह निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि गतिमान वस्तुओं में यांत्रिक ऊर्जा होती है।

क्रियाकलाप 3

ऊष्मीय ऊर्जा से परिचित कराना

छात्रों के अनुभवों की पुनरावृत्ति कराइए कि चाय की केतली में जब पानी खौलता रहता है तो केतली के ढक्कन में गति उत्पन्न हो जाती है। उनसे पूछिए:

ढक्कन को क्या होता है?

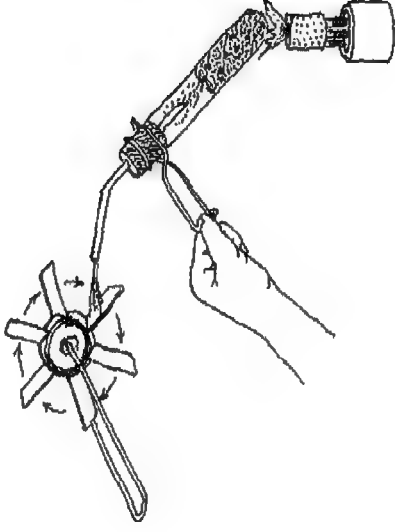
माचिस

ढक्कन ऊपर नीचे क्यों गति करता है ।
भाप कैसे बनती है?
इस बात पर बल दीजिए कि ऊष्मा, ऊर्जा का एक रूप है, और ऊष्मा से उत्पन्न भाप द्वारा वस्तुऐं गतिमान हो सकती हैं ।

क्रियाकलाप 4

उपकरणों को चित्र के अनुसार व्यवस्थित कीजिए । परखनली में पानी को खौलाइए । जेट द्वारा निकली भाप को चकरी की फलकों से टकराने दीजिए ।

क्वथन परखनली, मिट्टी के तेल का बर्नर, कार्क, जलचकरी, जेट (कांच), परखनली होल्डर, पानी

पूछिए:
चकरी को क्या होता है जब भाप इस चकरी की फलकों पर टकराती है?
चकरी को कौन गतिमान बनाता है?
(गतिमान भाप)
भाप बनाने के लिये ऊर्जा का कौन-सा रूप उपयोग में लाया जाता है?
(उष्मीय ऊर्जा)

गतिमान भाप जल चकरी को घुमा सकती है

क्रियाकलाप 5

छात्रों से कहिए कि कागज की फिरकी या कागज की कुण्डली, जैसी चित्र में दिखाई गई है, वैसी ही बनाएँ। इसे मिट्टी के तेल के बर्नर की लौ के ऊपर रखें।

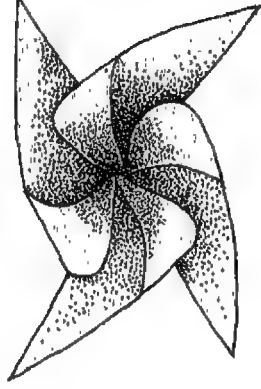
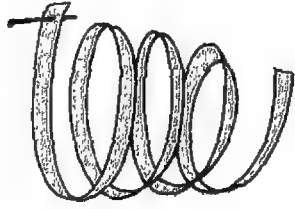
कागज की बनी फिरकी, मिट्टी के तेल का बर्नर, धागा, आलपीन

कागज की फिरकी या कागज की कुण्डली को लौ पर रखने पर क्या होता है?

यह क्यों गति करने लगी?

(ऊपर उठती हुई गर्म हवा के कारण)

ऊर्जा का कौन-सा रूप हवा को गतिमान कर रहा है?

(ऊष्मीय ऊर्जा)

फिरकी बनाना

क्रियाकलाप 6

अवगत कराना कि सूर्य ऊष्मीय ऊर्जा का प्रमुख स्रोत है

काले कागज का टुकड़ा, आवर्धक लेंस

छात्रों से विचार-विमर्श कीजिए कि सूर्य भी हमें ऊष्मीय ऊर्जा प्रदान करता है। उनसे पूछिएः

तुम्हें गर्मी का अनुभव कब होता है, धूप में या छाया में?

किसी वस्तु को धूप में रखने पर क्या होता है?

धूप में रखी वस्तुएँ क्यों अधिक गर्म हो जाती है?

गीले कपड़े क्यों धूप में फैलाए जाते हैं?

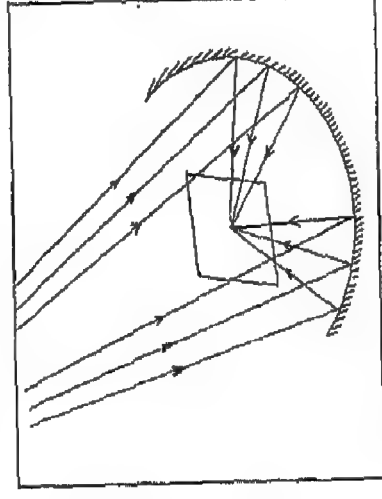
क्रियाकलाप 7

छात्रों से कहिए कि सूर्य की किरणों को आवर्धक लैंस द्वारा काले कागज पर एकत्र करें तथा निरीक्षण करें। जब सूर्य की किरणों को आवर्धक लैंस द्वारा एक काले कागज पर एकत्र किया जाता है, इस पर क्या प्रभाव होता है?

कागज क्यों धुआं देने तथा कुछ समय बाद जलने लगता है?
किस प्रकार की ऊर्जा इसे जलाने में उत्तरदायी है?

क्रियाकलाप 8

ग्लोब, काला कागज

ग्लोब को खोलिए । ग्लोब के दर्पण वाले भाग की अन्दरूनी सतह का उपयोग कीजिए ।
चित्र की भांति काले कागज के टुकड़े को सूर्य के प्रकाश में कुछ समय तक पकड़े रहिए ।
काले कागज पर क्या प्रभाव पड़ता है?
कागज क्यों जलने लग जाता है?
यह निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि ग्लोब के दर्पण वाले भाग के कारण सूर्य की किरणें कागज पर केन्द्रित हुईं, जिसके कारण कागज जलने लगा ।
इसी सिद्धान्त पर कार्य करने वाले अन्य उदाहरण जैसे सोलर कुकर के उदाहरण दीजिए ।
उन्हें समझाइए कि सूर्य, ऊर्जा का प्रमुख स्रोत है तथा पौधे अपना भोजन बनाने के लिए सौर ऊर्जा का उपयोग करते हैं ।

आवर्धक लैंस द्वारा सूर्य की किरणों के एकत्रण से काले कागज का जलना

क्रियाकलाप 9

छात्रों के अनुभवों की पुनरावृत्ति कीजिए और इस प्रकार के प्रश्न पूछिए:
तुम्हारी माताजी खाना बनाने के लिये कौन-से ईंधन का उपयोग करती हैं?

ईंधन उष्मीय ऊर्जा का सामान्य स्रोत है, इससे परिचित कराना

क्या यह ईंधन को बिना जलाए हुये खाना पकाती हैं?
ऐसा यह क्यों नहीं कर सकती?
ईंधन के जलने से किस प्रकार की ऊर्जा प्राप्त होती है?
स्टोव में कौन-सा ईंधन उपयोग में लाया जाता है?
लालटेन के जलाने में कौन-सा ईंधन उपयोग में लाया जाता है?
मोटर कार को चलाने में कौन-सा ईंधन उपयोग में लाया जाता है?
ट्रक के चलाने के लिये कौन-सा ईंधन उपयोग में लाया जाता है?
इस बात पर बल दीजिये कि सभी ईंधन जलने पर ऊष्मीय ऊर्जा देते हैं, तथा समझाइए कि ऊष्मीय ऊर्जा का बहुत से कार्यों में उपयोग होता है।
छात्रों से कहिए कि निम्नलिखित उदाहरणों से उन उदाहरणों का चयन करें जहाँ ऊष्मीय ऊर्जा का उपयोग होता है।

— जाड़ों में कमरे को गर्म रखने के लिए,
— मसाला पीसने के लिए,
— कपड़ों पर प्रेस करने के लिए,
— ईंट तथा मिट्टी के बर्तनों को पकाने के लिए,
— खिड़की खोलने में,
— पतंग उड़ाने में,
— लोहार द्वारा लोहे के टुकड़ों को गर्म करने तथा उनसे औजार बनाने में,
— शल्य चिकित्सा संबंधी उपकरण को जीवाणुहीन बनाने में,
— गाड़ी को खींचने में

क्रियाकलाप 10

विद्युत ऊर्जा से परिचित कराना

विचार-विमर्श द्वारा छात्रों के अनुभव की पुनरावृत्ति कराइए:
क्या होता है जब विद्युत-पंखे का स्विच खोल दिया जाता है?
क्या होता है जब विद्युत-पंखे का स्विच बन्द कर दिया जाता है?
ऊर्जा का क्या स्रोत है जो पंखे को चला देता है?
विद्युत-पंखा, पानी का कुंआ, विद्युत ग्राइंडर, ट्यूबवेल, हाथ का पंखा —
इनमें से कौन-सी वस्तुएँ विद्युत से संबंध नहीं रखती है?

यह निष्कर्ष निकालने में छात्रों को प्रोत्साहित कीजिए कि विद्युत द्वारा वस्तुएँ चलने लगती है । अतः यह भी ऊर्जा का एक रूप है जिसे विद्युत ऊर्जा कहते है ।

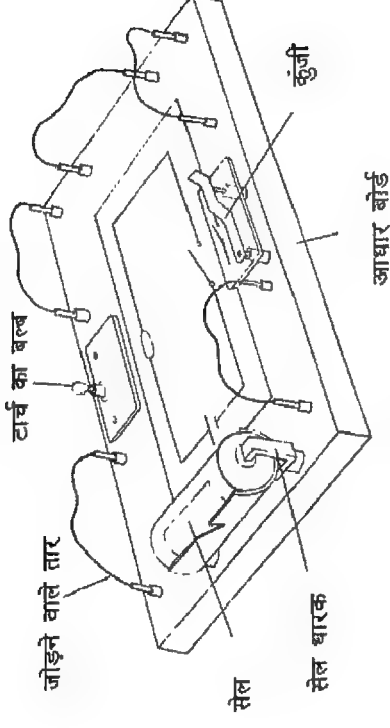
विस्तारण 1

विचार-विमर्श द्वारा छात्रों को विद्युत-ऊर्जा के स्रोतों, जैसे सेल, बैटरी विद्युत जनित्र (जैनेरेटर) आदि के बारे में बताइए । उनको कुछ बिजली घरों से भी अवगत कराइए जहाँ विद्युत ऊर्जा का उत्पादन होता है ।

**6.6:** ऊर्जा-रूपान्तरण क्या है?

**केंद्रित करें: ऊर्जा रूपान्तरण**

(कालांश 3-4)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| विद्युत ऊर्जा को यांत्रिक, ऊष्मीय, तथा प्रकाश ऊर्जा में रूपान्तरित किया जा सकता है, इस तथ्य से अवगत कराना | क्रियाकलाप 1<br>आटा पीसने वाली चक्की के बारे में छात्रों के अनुभवों की पुनरावृति कराइए:<br>आटा पीसने वाली चक्की को चलाने के लिए ऊर्जा का स्रोत क्या है?<br>चलती हुई आटा चक्की में किस प्रकार की ऊर्जा होती है?<br>(यांत्रिक ऊर्जा)<br>विद्युत पंखे को चलाने में किस प्रकार की ऊर्जा का रूपान्तरण होता है?<br>निष्कर्ष निकालने में छात्रों की सहायता कीजिए इन प्रक्रियाओं में विद्युत ऊर्जा, यांत्रिक ऊर्जा में बदल जाती है । | |
| | क्रियाकलाप 2<br>दिए गए विद्युत परिपथ बोर्ड द्वारा सेल की सहायता से टार्च बल्ब के उद्दीप्त होने का प्रदर्शन कीजिए ।<br>टार्च बल्ब को उद्दीप्त होने के लिए ऊर्जा का कौन-सा रूप चाहिए?<br>उद्दीप्त टार्च बल्ब किस प्रकार की ऊर्जा देता है?<br>समझाइए कि इस प्रक्रिया में विद्युत ऊर्जा, प्रकाश ऊर्जा में बदल जाती है ।<br>छात्रों से कहिए कि टार्च बल्ब को उद्दीप्त होने से पहले तथा बाद में छूएँ। | विद्युत परिपथ बोर्ड, बल्ब, सेल, सेल होल्डर, तार |

विद्युत परिपथ बोर्ड

पूछिएः
तुम क्या अनुभव करते हो?
इस प्रक्रिया में कौन-सी ऊर्जा, उष्मीय ऊर्जा में बदलती है?
यह निष्कर्ष निकालने में छात्रों को प्रोत्साहित कीजिए कि जब टार्च का बल्ब उद्दीप्त होता है तब विद्युत ऊर्जा का रूपान्तरण प्रकाश ऊर्जा में होता है और ऊष्मा ऊर्जा में भी।

क्रियाकलाप 3

यांत्रिक ऊर्जा को ऊष्मीय ऊर्जा में बदलने की क्रिया से अवगत कराना

छात्रों से कहिए कि अपनी हथेलियों को रगड़ें। उनसे पूछिएः
क्या अनुभव करते हो जब तुम अपनी हथेलियों को रगड़ते हो?
तुम्हारे हाथ क्यों गर्म हो जाते हैं?
इस प्रकार की प्रक्रिया में कौन-सी ऊर्जा, ऊष्मीय ऊर्जा में बदलती है?

क्रियाकलाप 4

पत्थर के दो टुकड़े

छात्रों से कहिए कि दो पत्थर के टुकड़ों को ताकत से रगड़ें।
पत्थर कब गर्म होते हैं, रगड़ने के पूर्व या रगड़ने के बाद?
कौन सी ऊर्जा ऊष्मीय ऊर्जा में बदल गई है?

यह निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि इन दोनों प्रक्रियाओं में यांत्रिक ऊर्जा, ऊष्मीय ऊर्जा में बदलती हैं ।

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| ऊष्मीय ऊर्जा के यांत्रिक ऊर्जा में बदलने की क्रिया से परिचित कराना | क्रियाकलाप 5<br>जल-चकरी को भाप द्वारा घुमाने की प्रक्रिया का पुनः स्मरण कराइए अथवा क्रियाकलाप 6.5.4 को दोहराइए ।<br>चकरी को घुमाने के लिए ऊर्जा का स्रोत क्या है?<br>(भाप)<br>घूमने वाली चकरी में किस प्रकार की ऊर्जा है?<br>इस प्रक्रिया में किस प्रकार की ऊर्जा का रूपान्तरण हो रहा है?<br>(ऊष्मीय ऊर्जा का यांत्रिक ऊर्जा में)<br>छात्रों के अनुभवों की पुनरावृति कीजिए कि चाय बनाते समय चाय की केतली का ढक्कन ऊपर-नीचे गति करता है और भाप की सहायता से भाप का ईंजन गति करता है ।<br>उनसे पूछिए:<br>चाय बनाते समय चाय की केतली का ढक्कन ऊपर नीचे क्यों गति करता है?<br>भाप कैसे बनती है?<br>ढक्कन को गति प्रदान करने वाली ऊर्जा का स्रोत क्या है?<br>चाय की केतली के ढक्कन में किस प्रकार की ऊर्जा निहित है?<br>इस प्रकार की प्रक्रिया में किस प्रकार की ऊर्जा का रूपान्तरण हो रहा है?<br>यह निष्कर्ष निकालने में छात्रों की सहायता कीजिए कि भाप ईंजन में, ऊष्मीय ऊर्जा, यांत्रिक ऊर्जा में बदलती है । | जलचकरी, मिट्टी के तेल का बर्नर, जेट, क्वथन परखनली, कार्क परखनली होल्डर, पानी |

## 6.7: ऊर्जा की बचत के लिए हम क्या कर सकते हैं?

केंद्रित करें: ऊर्जा संरक्षण

(कालांश 1)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| | क्रियाकलाप 1<br>छात्रों के दैनिक जीवन की परिस्थितियों के अनुभवों का पुनः स्मरण कराइए । | |

इस तथ्य का बोध कराना कि ऊर्जा के किसी भी रूप का समुचित उपयोग किया जाना चाहिए

विद्युत-पंखा तथा विद्युत-लैम्प की स्विच बंद क्यों करनी चाहिए, जब कमरे में कोई नहीं है?
क्या तुम्हारी माता, खाना पकाने वाली गैस/जलती लकड़ी/कोयला/मिट्टी के तेल के स्टोव आदि को खाना पकाने के बाद बंद कर देती है?
वह ऐसा क्यों करती हैं?
क्या गेहूं पिस जाने के बाद गेहूं पीसने वाली मशीन का स्विच बंद कर दिया जाता हैं?
ऐसा क्यों करते है?
इस बात पर बल दीजिए कि उपयोगी कार्य करने में ऊर्जा का समुचित उपयोग होना चाहिए।

**विस्तारण 1**

ऊर्जा संरक्षण में छात्र किस प्रकार सहायक हो सकते हैं?
छात्रों को प्रोत्साहित कीजिए कि वे ऊर्जा की बचत की विभिन्न प्रकार से संरक्षित करने को सूची तैयार करें। और इन्हें श्यामपट्ट पर लिखें।

# इकाई 7: पृथ्वी और आकाश

(आकाश और पृथ्वी)

**प्रस्तावना**

छात्रों ने आकाश में विभिन्न पिण्डों को देखा है। वे यह भी जानते हैं कि आकाश में दिखने वाले पिण्ड वास्तव में बहुत बड़े होते हैं। वे हमें छोटे दिखाई देते हैं क्योंकि वे हम से काफी दूर हैं। उन्हें चारों दिशाओं का भी ज्ञान है। उन्होंने चन्द्रमा की विभिन्न कलाओं को भी देखा है।

इस इकाई द्वारा छात्रः

- ग्रहों की विशेषताओं को पहचानने,
- उप-ग्रह की विशेषताएं जानने,
- प्राकृतिक और कृत्रिम उप-ग्रहों में अन्तर समझने,
- भारत द्वारा छोड़े गए कृत्रिम उपग्रहों की जानकारी प्राप्त करने,
- चन्द्रमा का पृथ्वी के परिक्रमण के कारण उसकी विभिन्न कलाएँ दिखाई देती है, स्मरण करने,
- पृथ्वी के परिभ्रमण (धूर्णन) से दिन और रात कैसे होते हैं, जानने,
- पृथ्वी 24 घण्टे में एक परिभ्रमण पूरा करती है, जानने,
- पृथ्वी सूर्य के चारों ओर परिक्रमण (परिक्रमा) करती है, इस कारण मौसम बदलते हैं जानने, में समर्थ होंगे।

**7.1:** ग्रह और उपग्रह एक दूसरे से किस प्रकार भिन्न हैं?

केंद्रित करें: ग्रह और उपग्रहों में अन्तर

(कालांश 4-5)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| ग्रहों की विशेषताएँ पहचानना | क्रियाकलाप 1<br>छात्रों से कहिए कि दो या तीन दिन रात में आकाश का निरीक्षण करें। उनके द्वारा आकाश में देखी गई वस्तुओं की उनसे चर्चा कीजिए।<br>उनसे पूछिएः<br>तुम्हें दिन के समय आकाश में कौन-कौन सी विभिन्न वस्तुएँ दिखाई देती हैं?<br>(सूर्य, बादल, आदि)<br>तुम्हें रात के समय आकाश में कौन-कौन सी विभिन्न वस्तुएँ दिखाई देती हैं?<br>(तारे, चन्द्रमा, आदि) | पर्यावरण, आकाश |

क्रियाकलाप 2

छात्रों को खेल के मैदान में ले जाइए किन्ही दस छात्रों को एक-एक बिल्ला (बैज) दीजिए ।
बिल्लों में से एक पर सूर्य (S) और बाकी पर नौ ग्रहों के नाम लिखे होने चाहिए ।
धरातल पर नौ वृत खींचिए । एक छात्र की पीठ पर बिल्ला (S) या "सूर्य" लगा कर वृत के कैंन्द्र में खड़ा कीजिए जैसा कि चित्र में प्रदर्शित है । शेष 9 छात्रों को अपनी-अपनी पीठ पर बिल्ला लगा कर अलग-अलग ग्रहों के नाम लिखे हुए चित्र के अनुसार एक-एक वृत्त पर खड़ा कीजिए । उनसे कहिए कि वामावर्त (घड़ी की सुई की उलटी दिशा) में गति करें । शेष छात्रों से कहिए कि उनकी गति देखें ।

खेल का मैदान इस विल्ले वृत्त खींचने के लिए लकड़ी का डंड़ा और एक रस्सी, स्कैच पेन

छात्रों को बताइए कि वृत्त के केन्द्र में खड़ा छात्र सूर्य को दर्शा रहा है, और शेष 9 छात्र अलग अलग उन नौ ग्रहों को प्रदर्शित करते हैं जो सूर्य की पीरक्रमा कर रहे हैं । जिस मार्ग पर ग्रह गति करते हैं उसे ग्रह की "कक्षा" कहते हैं । उन्हें यह भी समझाइए कि ये ग्रह, सूर्य के चारों तरफ घड़ी की सुई की विपरीत दिशा में गति करते हैं ।

उनसे पूछिएः
ग्रह क्या है?
(यह पिण्ड जो सूर्य की पीरक्रमा करता है ग्रह कहलाता है)

कक्षीय नौ ग्रहों के साथ सूर्य का प्रदर्शन

क्रियाकलाप 3

सौर परिवार का चार्ट बनाइए और छात्रों को निर्मित चार्ट की सहायता से बताइए कि ग्रह नौ होते हैं, जिनके नाम निम्नलिखित हैं:

सौर मंडल का चार्ट

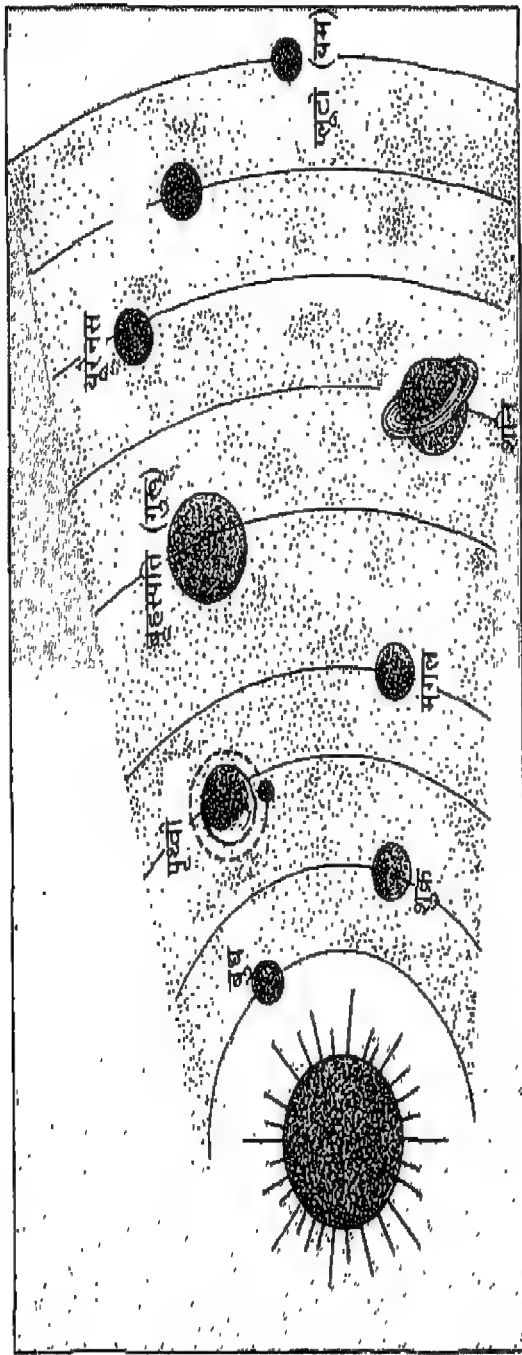
1. बुध
2. शुक्र
3. पृथ्वी
4. मंगल
5. बृहस्पति (गुरु)
6. शनि
7. यूरेनस
8. नेप्च्यून (वरुण)
9. प्लूटो (यम)

टिप्पणी: छात्रों को बताइए कि सूर्य से तीसरा ग्रह पृथ्वी है, जिस पर हम रहते हैं। पृथ्वी ठीक गेंद के सामान नहीं है, यह उत्तर तथा दक्षिण ध्रुवों पर हल्की सी दबी हुई है।

यह भी बताइए कि कुछ ग्रह रात में देखे जा सकते हैं, जैसे शुक्र, मंगल, आदि।

वे बहुत प्रकाशमान होते हैं और तारों की गति की विपरीत दिशा में गति करते हैं।

छात्रों का ध्यान निम्नलिखित तथ्यों की ओर आकर्षित कीजिए:

- बुध सबसे छोटा ग्रह है।
- बृहस्पति (गुरू) सबसे बड़ा ग्रह है।
- प्लूटो सबसे ठण्डा ग्रह है।
- बुध सबसे गर्म ग्रह है।
- प्लूटो सूर्य की एक परिक्रमा करने में सबसे अधिक समय लेता है।
- बुध, सूर्य की एक परिक्रमा करने में सबसे कम समय लेता है।
- शनि ग्रह के चारों ओर वलय (रिंग) होते हैं।

सौर परिवार

छात्रों से कहिए कि उपर्युक्त जानकारी नीचे दी गई सारणी में भरें।

| ग्रहों की विशेषता | ग्रहों के नाम |
|---|---|
| सबसे गर्म ग्रह | बुध |
| सबसे ठण्डा ग्रह | — |
| सूर्य से निकटतम ग्रह | — |
| सूर्य से सबसे अधिक दूरी वाला ग्रह | — |
| ग्रह जिसमें वलय होते हैं | — |
| ग्रह जो सूर्य की परिक्रमा में सबसे अधिक समय लेता है | — |
| ग्रह जो सूर्य की परिक्रमा में सबसे कम समय लेता है | — |

| | | |
|---|---|---|
| पहचानना कि चन्द्रमा एक उपग्रह है | क्रियाकलाप 4<br>चित्रानुसार किट बाक्स पर पृथ्वी चन्द्रमा के मॉडल की व्यवस्था करने में छात्रों की सहायता कीजिए। उनको बताइए कि बड़ी गेंद/ग्लोब (ई) पृथ्वी दर्शाती है और छोटी गेंद (एम) चन्द्रमा को प्रदर्शित करती है। उनसे कहिए कि छोटी गेंद (एम) को बड़ी गेंद/(ग्लोब) (ई) के चारों ओर घुमाएँ। उन्हें समझाइए कि चन्द्रमा जो पृथ्वी की परिक्रमा करता है, पृथ्वी का उपग्रह है। उन्हें यह भी बताइए कि कोई भी पिण्ड जो किसी ग्रह की परिक्रमा करता है, उपग्रह कहलाता है।<br>हमारे सौर मंडल में अनेक प्राकृतिक उपग्रह है। चन्द्रमा, पृथ्वी का एक प्राकृतिक उपग्रह है।<br><br>विस्तारण 1<br>छात्रों से कहिए कि तारों, ग्रहों और उपग्रहों की श्रेणी में आने वाले आकाशीय पिण्डों की सूची बनाएँ।<br><br>विस्तारण 2<br>छात्रों से कहिए कि विभिन्न उपग्रहों के चित्र खींचें अथवा कहीं से लेकर अपनी नोट बुक पर चिपकाएँ।<br><br>विस्तारण 3<br>यदि सम्भव हो तो किसी निकट के कृत्रिम नभोंमंडल को दिखाने ले जाइए। | पृथ्वी-चन्द्रमा मॉडल (ग्लोब, छोटी गेंद, और संलग्नी) |

**7.2: प्राकृतिक उपग्रह कृत्रिम उपग्रह से किस प्रकार भिन्न हैं?**
केंद्रित करें: चन्द्रमा प्राकृतिक उपग्रह के रूप में

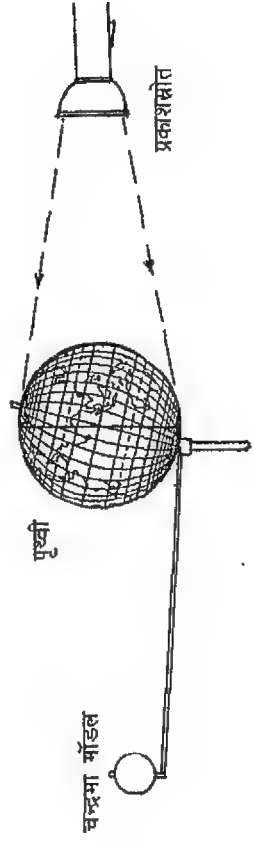
(कालांश 2-3)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| पृथ्वी के चारों ओर के प्राकृतिक उपग्रहों को पहचानना तथा नामांकन करना | क्रियाकलाप 1<br>छात्रों से कहिए कि ज्ञात उपग्रहों के नाम बताएँ।<br>उनसे पूछिए:<br>उनके द्वारा बताए गए उपग्रहों और चन्द्रमा में क्या कोई अन्तर है?<br>उनको बताइए कि चन्द्रमा पृथ्वी का एक प्राकृतिक उपग्रह है जबकि अन्य उपग्रह जिनके नाम उन्होंने बताए हैं और जो मानव द्वारा निर्मित एवं कक्षाओं में स्थापित किए गए है कृत्रिम उपग्रह कहलाते हैं। | |

| | क्रियाकलाप 2 | |
|---|---|---|
| दो या तीन कृत्रिम उपग्रहों के नाम जानना और उनको पहचानना | कृत्रिम उपग्रहों के चित्र एकत्र कर कागज पर चिपकाइए तथा उन्हें नामांकित कीजिए । भारत द्वारा छोड़े गए उपग्रहों के चित्रों को अलग-अलग छांटिए । भारत द्वारा छोड़े गए उपग्रहों के नाम छात्रों से पूछिए । इन नामों को लिखिए । (आर्य भट्ट, भास्कर, रोहिणी, एप्पल, इनसेट-1ए, इनसेट-1बी, इनसेट-1सी) । भारत संसार के उन छः देशों में से एक है जिन्होंने उपग्रह छोड़े हैं । | |

**7.3: चन्द्रमा की कलाओं को उसके द्वारा की गई पृथ्वी की परिक्रमा से हम कैसे सम्बन्धित करते हैं?**
**केंद्रित करें: पृथ्वी के संदर्भ में चन्द्रमा की कलाएं**

(कालांश 1)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| | क्रियाकलाप 1 | |
| चन्द्रमा की कलाओं तथा पृथ्वी की परिक्रमा करने में सम्बंध जानना | चन्द्रमा की विभिन्न कलाओं का स्मरण कराइए । चन्द्रमा के मॉडल को किट पर चित्रानुसार व्यवस्थित करने में छात्रों की सहायता कीजिए । यह प्रयोग अन्धेरे कमरे में करना अधिक उचित होगा । एक टार्च/मोमबत्ती से चन्द्रमा के ग्लोब पर प्रकाश डालकर छोटी गेंद को पृथ्वी के चारों ओर घुमाकर चन्द्रमा की विभिन्न कलाओं को प्रदर्शित कीजिए । यहां टार्च/मोमबत्ती सूर्य को प्रदर्शित करता है । उन्हें समझाइए कि सूर्य का वह प्रकाश जो हमें चन्द्रमा से आता प्रतीत होता है, चन्द्रमा की विभिन्न स्थितियों पर निर्भर करता | पृथ्वी-चन्द्रमा मॉडल, टार्च/मोमबत्ती |

चन्द्रमा की एक कला

है जब वह पृथ्वी की परिक्रमा करता है। इस क्रियाकलाप में चन्द्रमा की दिखाई देने वाली विभिन्न कलाओं का चित्र खींचने का छात्रों को परामर्श दीजिए। उनके द्वारा कक्षा 3 में क्रियाकलाप 5.6.2 के संदर्भ में आकाश में देखी गई चन्द्रमा की कलाओं से इनकी तुलना करने हो कहिये।

**7.4:** दिन और रात कैसे होते हैं?

केंद्रित करें: पृथ्वी के परिभ्रमण (घूर्णन) के कारण दिन रात होते हैं। (कालांश 2-

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| यह जानना कि पृथ्वी का वह भाग जो सूर्य के सामने होता है वहाँ दिन होता है और जो सामने नहीं होता वहाँ रात होती है। | क्रियाकलाप 1<br>प्रश्नों द्वारा छात्रों से दिन रात होने के विषय में चर्चा कीजिए।<br>तुम प्रकाश के लिए स्विच कब खोलते हो अथवा बत्ती कब जलाते हो? (जब अन्धेरा होता है)<br>अन्धेरा कब होता है? (रात में)<br>रात में अन्धेरा क्यों होता है? (क्यों कि वहां सूर्य का प्रकाश नहीं होता है)<br>जब सूर्य का प्रकाश होता है तब क्या होता है? (दिन होता है)<br>दिन और रात क्यों होते हैं?<br>क्या पृथ्वी के सब स्थानों पर एक ही समय दिन/रात होते हैं?<br>(नहीं, कहीं दिन और उसी समय कहीं रात होती है) | |
| | क्रियाकलाप 2<br>छात्रों से कहिए कि चित्र के अनुसार ग्लोब अथवा गेंद (पृथ्वी का प्रतीक) में एक छड़ इस प्रकार लगाएँ कि ग्लोब अथवा गेंद उसके चारों ओर स्वतंत्र रूप से घूम सके। इसे स्टैण्ड पर लगाइए।<br>इसके ऊपर टार्च या जलती मोमबत्ती से प्रकाश डालिए और छात्रों से कहिए कि इसका निरीक्षण करें।<br>यह निष्कर्ष निकालने के लिये उन्हें प्रोत्साहित कीजिए कि ग्लोब/गेंद, पृथ्वी के समान है और टार्च/मोमबत्ती सूर्य के समान है। ग्लोब के समान पृथ्वी के उस भाग पर थी जहां सूर्य का प्रकाश पड़ता है वहां दिन होता है और जो दूसरी ओर होता है (जहाँ प्रकाश नहीं पहुंचता) रात कहलाती है। | गेंद/ग्लोब, स्टैण्ड टार्च/मोमबत्ती |

उनसे पूछिएः
दिन के बाद क्या आता है?
रात के पश्चात् क्या आता है?
ऐसा क्यों होता है?

पूछिएः
उन देशों के नाम बताइये जो ग्लोब के प्रकाशित भाग में स्थित हैं?
भारत पर जब टार्च/मोम बत्ती का प्रकाश पड़ता है तब उन देशों के नाम बताइये जहाँ दिन होता है ।
किसी छात्र से ग्लोब/गेंद के प्रकाशमय भाग पर "क" तथा अंधेरे भाग पर "ख" अंकित करने को कहिए ।
ग्लोब/गेंद का कौन सा भाग प्रकाशमय और कौन सा भाग अन्धकारमय है?
गेंद/ग्लोब का कौन सा भाग प्रकाशमय है?
गेंद/ग्लोब का कौन सा भाग अंधकारमय है?
तुम क्या निष्कर्ष निकालते हो?
छात्र से कहिए कि ग्लोब/गेंद को इस प्रकार घुमाएं कि अंधेरा भाग प्रकाश में आ जाए, जैसा चित्र में प्रदर्शित है ।
उनसे पूछिएः
अब पृथ्वी का कौन सा भाग प्रकाशमय है?
अब पृथ्वी का कौन सा भाग अन्धकारमय है?
ऐसा क्यों हुआ?
तुम क्या निष्कर्ष निकालते हो?
यदि गेंद/ग्लोब (पृथ्वी) एक परिक्रमा पूरा कर ले तो कितने रात और दिन होंगे?
छात्रों से कहिए कि पृथ्वी इस गेंद/ग्लोब जैसी है और छड़, जिसके चारों तरफ वह घूमती है उसे गेंद/ग्लोब (पृथ्वी) का अक्ष कहते हैं । वास्तव में पृथ्वी में ऐसी कोई छड़ नहीं होती है । यह एक काल्पनिक रेखा है जो पृथ्वी के उत्तर और दक्षिण ध्रुव से होकर जाती है, जिसके चारों ओर पृथ्वी परिभ्रमण करती है । इसे पृथ्वी का अक्ष कहते हैं । यह अक्ष ठीक उर्ध्वाधर नहीं होता, वरन् थोड़ा तिरछा (झुका हुआ) होता है जैसा कि चित्र में दिखाया गया है ।
उन्हें यह समझाने का प्रयत्न कीजिए कि पृथ्वी के अपने अक्ष के चारों ओर परिभ्रमण के कारण ही क्रमशः दिन और रात होते हैं ।

क्रियाकलाप 3
छात्रों से कहिए कि किसी दिन प्रातः पाँच बजे से प्रारम्भ कर दूसरे दिन प्रातः पाँच बजे तक व्यतीत हुए घंटों

| | | |
|---|---|---|
| यह जानना कि पृथ्वी द्वारा एक परिभ्रमण पूरा करने में चौबीस घंटे का समय लगता है। | को गिनें। <br>निम्नलिखित प्रश्न पूछिएः <br>प्रातः पाँच बजे से अगले दिन प्रातः बजे तक कुल कितने घण्टे होते हैं? <br>एक पूरे दिन (1दिन+1रात) में कितने घण्टे होते हैं? <br>पृथ्वी को अपने अक्ष पर परिभ्रमण पूरा करने में कितना समय लगता है? <br>(अक्ष पर एक परिभ्रमण, पृथ्वी चौबीस घण्टों में पूरा करती है) <br><br>**विस्तारण 1** <br><br>छात्रों से कहिए किः <br>— पृथ्वी की गति के कारण दिन-रात होने का चार्ट बनाइए; <br>— पता लगाएंकि सूर्य के सामने होने के कारण जब भारत में दिन होता है तो जापान, इग्लैण्ड, यू.एस.ए., <br>— रूस आदि देशों में रात होगी या दिन (यह जानकारी प्राप्त करने के लिए टार्च और ग्लोब का वे उपयोग कर सकते हैं); <br>— दिन के बाद रात और रात के बाद दिन होने का माडल बनाएँ। | टार्च, ग्लोब |

**7.5: क्या पृथ्वी के परिभ्रमण के कारण ऋतुएँ होती है?**

केंद्रित करें: पृथ्वी के परिभ्रमण के कारण ऋतुओं का होना

(कालांश 2-3)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| | क्रियाकलाप 1 | |
| पृथ्वी द्वारा सूर्य की परिक्रमा करने और ऋतुओं में होने वाले परिवर्तनों में संबंध ज्ञात करना | ऋतुओं के संबंध में छात्रों से निम्नलिखित प्रश्न पूछ कर परिचर्चा कीजिएः <br>कुछ दिनों बहुत गर्मी और कुछ दिनों बहुत सर्दी होती है, ऐसा क्यों होता है? <br>एक वर्ष में कितनी ऋतुएँ होती हैं? <br>आजकल कौन-सी ऋतु चल रही है? <br>इस ऋतु के पश्चात् कौन-सी ऋतु आएगी? <br>इसके पश्चात् क्रम से अगली कौन सी ऋतु आएगी? <br>ऐसा क्यों होता है? | |

## क्रियाकलाप 2

यह समझना कि ऋतुओं मे परिवर्तन सूर्य की किरणों के पृथ्वी तक भिन्न-भिन्न दूरियों से पहुंचने के कारण होता है

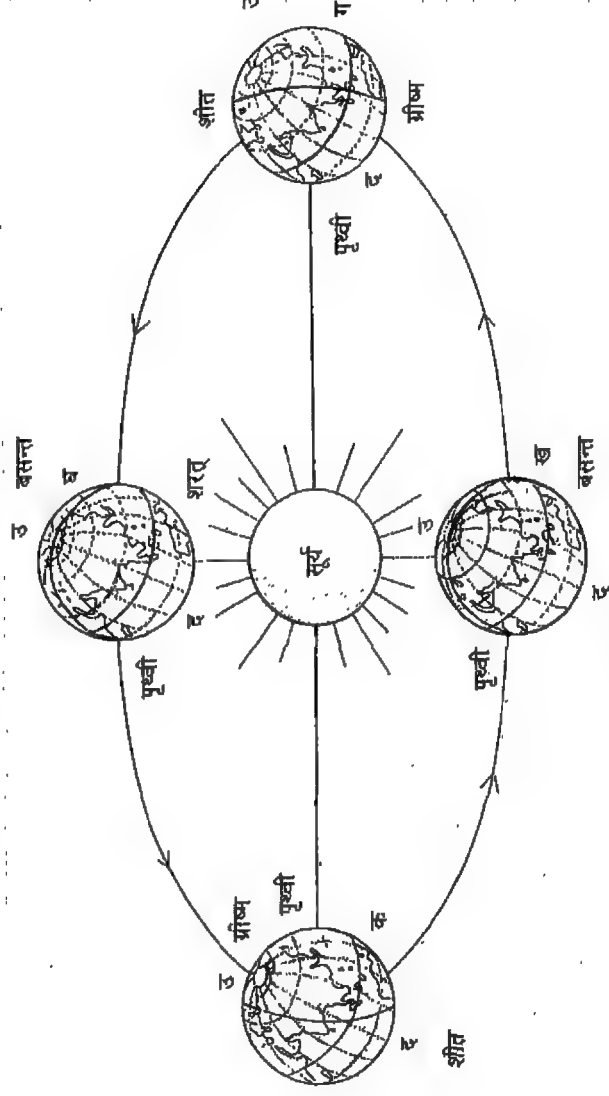
गेंद/ग्लोब, छड़, पीली गेंद (सूर्य), एक छोटी गेंद

मेज पर एक अंडाकार चित्र खींचिए। दर्शाए गए चित्र के अनुसार उसके केन्द्र पर पीली गेंद (सूर्य) रखिए। एक गेंद/ग्लोब जिसमें छड़ लगी हो और उसे क, ख, ग, घ, भिन्न-भिन्न स्थितियों में रखकर छात्रों को उसे क्रमशः देखने को कहिए।

छात्रों से कहिए कि पृथ्वी की झुकी हुई अक्ष (धुरी) को देखें। उनसे पूछिएः

ग्रीष्म ऋतु किस स्थिति में होती है?

शरद ऋतु किस स्थिति में होती है?

उन्हें समझाइए कि "क" स्थिति में उत्तरी गोलार्द्ध (छड़ पर "उ" का चिंह)
सूर्य की ओर झुका होता है और दक्षिणी गोलार्द्ध (छड़ पर "द" का चिन्ह) सूर्य से दूसरी ओर झुका होता है। इस कारण उत्तरी भाग में गर्मी होती है और दक्षिणी भाग में सर्दी होती हैं।

ऋतुओं का होना का प्रदर्शन

''ग'' की स्थिति में उत्तरी भाग सूर्य से दूर होने के कारण वहाँ सर्दी होती है। दक्षिणी भाग सूर्य के पास होने के कारण वहाँ गर्मी होती है।

''ख'' और ''घ'' की स्थितियों में, उत्तरी गोलार्द्ध में क्रमशः शरद् और वसन्त होंगे; तथा दक्षिणी गोलार्द्ध में क्रमशः बसन्त और शरद् होंगे।

जैसे जैसे पृथ्वी ''क'' की स्थिति से ''ग'' तक घूमती जाती है; उत्तरी भाग सूर्य से दूर होता जाता है। इस कारण उत्तरी भाग का तापमान क्रमशः घटने लगता है और वहाँ सर्दी होने लगती है। ''ख'' पर उत्तरी भाग में बसन्त ऋतु और दक्षिणी भाग में शरद् ऋतु होंगी।

इसी प्रकार जब पृथ्वी ''ग'' से ''घ'' की तरफ आती है तो उत्तरी भाग में तापमान धीरे-धीरे बढ़ने लगता है और दक्षिणी भाग में तापमान कम होने लगता है। इन्हीं कारणों से ''घ'' की स्थिति में उत्तरी भाग में बसन्त और दक्षिणी भाग में शरद ऋतु होती है।

टिप्पणीः मैदानों में तीन ऋतुएँ होती है-ग्रीष्म, शीत और वर्षा और पहाडों पर चार ऋतुएँ होती है-ग्रीष्म, शीत, शरद, और बसन्त।

क्रियाकलाप 3

छात्रों से ऋतुओं के बारे में विचार-विमर्श कीजिए।

उनसे पूछिएः

क्या उत्तरी और दक्षिणी ध्रुवों पर एक जैसे महीनों में गर्मी अथवा सर्दी पड़ती हैं?

(नहीं)

हमारे यहां गर्मी किन महीनों में पड़ती है?

हमारे यहां सर्दी किन महीनों में पड़ती है?

क्या प्रति वर्ष ये निश्चित महीनों में ही पड़ती है?

उन्हें समझाइए कि पृथ्वी के परिभ्रमण के कारण ऐसा होता है। पृथ्वी को सूर्य की एक परिक्रमा पूरी करने में 365/¼ दिन लगते हैं और पृथ्वी प्रति वर्ष फिर अपनी पूर्व अवस्था में इन्ही महीनों (सौर मास) में आ जाती है। इसी कारण प्रत्येक वर्ष गर्मी और सर्दी निश्चित महीनों में ही पड़ती हैं।

टिप्पणीः

1. एक अधि-वर्ष 366 दिनों का होता है और प्रत्येक चौथे वर्ष आता है।
2. चन्द्रमा, पृथ्वी की एक परिक्रमा पूरी करने में 27⅓ दिन लेता है।
3. कभी-कभी चन्द्रमा दिन के समय भी दिखाई देता है। यह सौर-मास और चन्द्र-मास में अन्तर के कारण होता है।

**7.6: क्या हमारे त्यौहार सांस्कृतिक गतिविधियाँ और भारतीय कलेण्डर (पंचांग) आकाशीय पिण्डों से संबन्धित है?**

**केंद्रित करें: त्यौहार तथा ऋतुएं**

(कालांश 1-2)

| अधिगम परिणाम | प्रस्तावित शिक्षण प्रक्रम | साधन एवं सामग्री |
|---|---|---|
| यह जानना कि भारतीय त्यौहार और गतिविधियां, एवं पंचांग भी आकाशीय पिण्डों से संबन्धित हैं | क्रियाकलाप 1<br>छात्रों से भारतीय त्यौहार और गतिविधियों के संबंध में परिचर्चा कीजिए।<br>उनसे पूछिए:<br>तुम कौन-कौन से त्यौहार मनाते हो?<br>कौन से महीनों में हम ये त्यौहार मनाते हैं?<br>त्यौहारों और उनके महीनों की छात्रों से सूची बनवाइए।<br>क्या ये त्यौहार आकाशीय पिण्डों से जुड़े हैं?<br>क्या हमारा भारतीय पंचांग चन्द्रमा की कलाओं पर आधारित है?<br>(हां)<br>उन्हें समझाइए कि भारतीय चन्द्र-माह का पहला दिन अमावस्या के अगले दिन से शुरू होता है, और अमावस्या महीने का अन्तिम दिन होता है। इसे एक चन्द्र-माह कहते हैं। | |

क्रियाकलाप 2

छात्रों से कहिए कि अमावस्या और पूर्णिमा को आने वाले त्यौहारों की सूची बनाएँ।
उनसे निम्नलिखित सारणी की पूर्ति कराइए ।

| त्यौहार जो मनाये जाते हैं | |
|---|---|
| अमावस्या | पूर्णिमा |
| दिवाली | होली |
| — — — | बुद्ध पूर्णिमा |
| — — — | रक्षा-बन्धन |
| — — — | गुरू नानक जन्म-दिवस |

**टिप्पणीः**

भारतीय पंचांग चन्द्रमा की गति पर और अंग्रेजी पंचांग सूर्य की गति पर आधारित है । भारतीय महीनों के नाम निम्न हैं:

चैत्र, बैशाख, ज्येष्ठ, आषाढ़, श्रावण, भाद्रपद, आश्विन, कार्तिक, मार्गशीर्ष, पौष, माघ, फाल्गुन ।

## परिशिष्ट 1

कक्षा 4 के लिए पर्यावरणीय अध्ययन-विज्ञान हेतु शिक्षक-पुस्तिका की पाण्डुलिपि तैयार, करने, समीक्षा, संशोधन करने एवं अंतिम रूप देने के लिए विभिन्न स्तरों पर दिल्ली में वर्ष 1987-88 में आयोजित कार्यशालाओं के प्रतिभागी

**सलाहकार समिति**

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**सम्पादक दल**

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   केन्द्रीय विद्यालय
   पुष्प विहार
   साकेत
   नयी दिल्ली

2. श्रीमती आई. आहलूवालिया
   केन्द्रीय विद्यालय
   आई.आई.टी. परिसर
   हौज खास
   नयी दिल्ली

3. डा.बी.डी. अत्रेय
   22, ए.जी.सी.आर. एन्कलेव
   नयी दिल्ली

4. श्रीमती सुमन भगत
   एम.सी.डी. प्राथमिक विद्यालय
   बाग करे खान
   दिल्ली

5. कु. प्रेम बहाकू
   एन.पी. प्राइमरी एन.डी.एम.सी. स्कूल
   रेस कोर्स
   नयी दिल्ली

6. श्रीमती सुखवन्त कौर भंडारी
   एस.जी.एन. खालसा एम.सी.डी.
   प्राइमरी स्कूल
   अहाता किदारा
   दिल्ली

7. कु. पवन चन्दोक
   ऑक्सफोर्ड सीनियर
   सैकेन्ड्री स्कूल
   ई-ब्लाक, विकासपुरी
   नयी दिल्ली

8. श्रीमती प्रीति चावला
   एयर फोर्स बाल भारती स्कूल
   लोदी रोड
   नयी दिल्ली

9. श्रीमती एस. चोकरा
केन्द्रीय विद्यालय
जे.एन.यू. परिसर
नई मैहरौली रोड़
नयी दिल्ली

10. श्री अशोक कुमार खन्ना
एम.सी. प्राइमरी मॉडल स्कूल
(एम.सी.डी)
गुलाबी बाग
दिल्ली

11. श्रीमती उषा खेर
केन्द्रीय विद्यालय
एन.सी.ई.आर.टी. परिसर
श्री अरविन्द मार्ग
नयी दिल्ली

12. श्रीमती प्रोमिला मदान
भारतीय विद्या भवन
कस्तूरबा गाँधी मार्ग
नयी दिल्ली

13. श्रीमती विनीतां मेहरा
दिल्ली पब्लिक स्कूल
एफ. ब्लाक, पूर्वी कैलाश
नयी दिल्ली

14. श्रीमती जया मेहता
मदर इन्टरनेशनल स्कूल
श्री अरविन्द मार्ग
नयी दिल्ली

15. श्रीमती आशा नरूला
एन.पी. प्राइमरी छात्र
(एन.डी.एम.सी.) स्कूल
नं. 1, लोदी रोड़
नयी दिल्ली

16. श्री एच.आर. पहुजा
एम.सी. छात्र प्राइमरी
स्कूल (एम.सी.डी.)
श्रीनिवासपुरी
नयी दिल्ली

17. श्री जोस पॉल
टीर्चस सेन्टर
एजूकेशनल प्लानिंग ग्रुप
सेन्ट जेवियर परिसर स्कूल
4, राज निवास मार्ग
दिल्ली

18. श्रीमती ललित राज
एपीजे स्कूल
शेख सराय फेज -1
नयी दिल्ली

19. श्रीमती सरोजा रामचन्द्रन
दिल्ली पब्लिक स्कूल
बसन्त विहार
नयी दिल्ली

20. श्रीमती इन्दु शर्मा
एन.डी.एम.सी. जूनियर
नवयुग स्कूल
लक्ष्मी बाई नगर
नयी दिल्ली

21. कु. ममता शर्मा
केन्द्रीय विद्यालय
जे.एन.यू. परिसर
नई मैहरौली रोड़
नयी दिल्ली

22. श्री मुकेश कुमार शर्मा
एम.सी. प्राइमरी स्कूल (एम.सी.डी.)
शास्त्री नगर
दिल्ली

23. श्री जय देव सिंह
एम.सी.डी. प्राइमरी स्कूल
ब्रह्म पुरी XI
दिल्ली

24. श्रीमती हरवीर ज. सिंह
एयर फोर्स बाल भारती स्कूल
लोदी रोड़
नयी दिल्ली

25. श्री सत्य पाल सिंह
एम.सी. प्राइमरी स्कूल (एम.सी.डी.)
पूर्वी लक्ष्मी मार्केट
दिल्ली

26. श्रीमती सरोजा श्रीनिवासन
रामजस स्कूल
सैक्टर 4, आर.के. पुरम
नयी दिल्ली

27. श्री सी. एम. श्रीवास्तव
विज्ञान शिक्षण विभाग
एस.सी.ई.आर.टी.
3, लिंक रोड, करोल बाग
नयी दिल्ली

28. श्रीमती सरोजा सुन्दराजन
टीचर्स सेन्टर
स्प्रिंगडेल स्कूल
नयी दिल्ली

29. श्री राजेन्द्र स्वामी
एम.सी.डी. प्राइमरी स्कूल
राधे श्याम पार्क ॥
कृष्णा नगर
दिल्ली

30. श्रीमती सन्तोष ठाकुर
एन.पी. प्राइमरी (एन.डी.एम.सी.)
स्कूल नं.2
हेवलाक स्क्वायर
नयी दिल्ली

31. श्रीमती नीना विशिन
बिरला विद्या निकेतन
पुष्प विहार
नयी दिल्ली

32. श्रीमती वीना यादव
मदर्स इन्टनेशनल स्कूल
श्री अरबिन्द मार्ग
नयी दिल्ली

33. डा. भूपेन्द्र सिंह
गवरमेन्ट छात्र सीनियर
सैकेन्ड्री स्कूल
अशोक नगर
नई दिल्ली

34. डा.एस.पी. दुबे
रामजस कालेज
दिल्ली विश्वविद्यालय
दिल्ली

35. डा. श्रीमती अरूणा मोहन
गार्गी कालेज
सिरी फोर्ट रोड़
नई दिल्ली

36. डा. राज
नवयुग स्कूल
सरोजनी नगर
नई दिल्ली

## शैक्षिक दल

| मध्य प्रदेश | उत्तर प्रदेश | रा.शै.अ.प्र.प. |
|---|---|---|
| श्री एस.बी. गुप्ता | श्री आर.एस. रस्तोगी | डा. बी.के. शर्मा (शैक्षिक दल समन्वयक) |
| श्री वाई.एस. डण्डोतिया | श्री एस.एस. श्रीवास्तव | डा. एच. ओ. गुप्ता |
| श्री जी.आर. सरवाईकर | श्री एस.के. श्रीवास्तव | डा. एस.सी. जैन |
| | श्री वी.एस. कटियार | श्री ए.के. गुप्ता, जे.पी.एफ. |
| | श्री बी.बी. विश्वकर्मा | श्री ए.के. शुक्ला, जे.पी.एफ. |
| | श्री एच.के.एल. शाह | |
| | श्री जे.सी. मिश्रा | |

## परिशिष्ट 2

कक्षा चार के लिए पर्यावरणीय अध्ययन-विज्ञान हेतु शिक्षक पुस्तिका तथा प्राथमिक विज्ञान किट के अभिविन्यास एवं परीक्षण कार्यक्रमों में उत्तर प्रदेश, मध्य प्रदेश और दिल्ली में अप्रैल/मई 1988 में आयोजित कार्यक्रमों के प्रतिभागी

1. श्री महेश वगवाईया<br>शासकीय प्राईमरी स्कूल<br>मुल्लानी<br>सिहोर (म.प्र.)
2. श्री अशोक चौहान<br>शासकीय सुभाष मिडिल स्कूल<br>सिहोर (म.प्र.)
3. श्री मनोहर गुप्ता<br>शासकीय प्राईमरी स्कूल<br>इमलिया नरेन्द्र<br>सी.न. 2, बेरसिया<br>भोपाल (म.प्र.)
4. श्री आर.जी. नेमा<br>चन्द्रशेखर आजाद मिडिल स्कूल<br>भोपाल (म.प्र.)
5. श्री ओ.पी. शर्मा<br>शासकीय प्राईमरी स्कूल<br>सिक्योर्टि लाइन्स<br>भोपाल (म.प्र.)
6. श्री जे.एन. श्रीवास्तव<br>शासकीय मिडिल स्कूल<br>अरेरा कालोनी<br>भोपाल (म.प्र.)

7. श्री बसन्त सिंह<br>कस्तूरबा हाई स्कूल<br>भोपाल (म.प्र.)

8. श्री एस.बी. सिंह<br>शासकीय विवेका हाई स्कूल<br>सिहोर (म.प्र.)

9. श्री सी.पी. सिंह<br>शासकीय प्राईमरी स्कूल<br>बिजौरा (म.प्र.)

10. श्री शैलेन्द्र श्रीवास्तव<br>शासकीय गर्ल्स प्राईमरी स्कूल<br>सी.न. 1, बेरसिया<br>भोपाल (म.प्र.)

11. श्रीमती सुमन ठाकुर<br>शासकीय संजय गांधी मिडल स्कूल<br>भोपाल (म.प्र.)

12. श्री राज बहादुर<br>जूनियर बेसिक विद्यालय<br>तुलसी पुर<br>इलाहाबाद (उ.प्र.)

13. श्रीमती आशा ईसुवियुस<br>राजकीय बेसिक डिमोंस्ट्रेशन स्कूल<br>सी.पी.आई.<br>इलाहाबाद (उ.प्र.)

14. श्री लाल बहादुर जायसवाल<br>जूनियर बेसिक विद्यालय<br>नैनी बाजार<br>इलाहाबाद (उ.प्र.)

15. श्री सुरेश नारायण मिश्रा<br>प्राईमरी पाठशाला<br>फाफामाऊ<br>इलाहाबाद (उ.प्र.)

16. श्री कमलेश नारायण मिश्रा<br>प्राईमरी पाठशाला<br>करेलाबाग गांव<br>इलाहाबाद (उ.प्र.)

17. श्री कृपा शंकर मिश्रा<br>जूनियर बेसिक विद्यालय<br>रिजर्व पुलिस लाइन<br>लखनऊ (उ.प्र.)

18. श्री राम विलास मिश्रा<br>जूनियर बेसिक प्राईमरी स्कूल<br>सादतगंज<br>लखनऊ (उ.प्र.)

19. श्री शिव दरशन मिश्रा<br>राजकीय शोध विद्यालय<br>(एस.आई.ई.से जुड़ा हुआ)<br>इलाहाबाद (उ.प्र.)

20. श्री शारदा प्रसाद तिवारी<br>प्राईमरी पाठशाला<br>इस्माइल गंज<br>लखनऊ (उ.प्र.)

21. श्रीमती शारदा शर्मा<br>जूनियर बेसिक विद्यालय<br>चिनहट<br>लखनऊ (उ.प्र.)

22. श्री राधे श्याम<br>प्राइमरी पाठशाला<br>कौड़िहार<br>इलाहाबाद<br>(यू.पी.) उ.प्र.)

23. श्री प्रभाशंकर शुक्ल<br>बेसिक प्राइमरी पाठशाला<br>निटगतगंज<br>लखनऊ<br>(उ.प्र.)

24. श्री राम कमल शुक्ल<br>आदर्श विद्यालय<br>(संलग्न रा.इ.का.)<br>लखनऊ

25. श्री प्रभाकर वर्धन सिंह
प्राईमरी पाठशाला
थारवाई
इलाहाबाद (उ.प्र.)

26. श्री रघुनन्दन सिंह
पी.ए.सी. विद्या मन्दिर
35, पी.ए.सी.
लखनऊ (उ.प्र.)

27. श्रीमती अमरलता श्रीवास्तव
प्राईमरी पाठशाला
रैहींकला
लखनऊ (उ.प्र.)

28. श्रीमती कामिनी श्रीवास्तव
जूनियर बेसिक कन्या विद्यालय
चिनहट
लखनऊ (उ.प्र.)

29. श्री मरछू यादव
राजकीय आदर्श विद्यालय
(नोरमल विद्यालय से जुड़ा हुआ)
शिवकुटी
इलाहाबाद (उ.प्र.)

30. श्री उमा शंकर यादव
जूनियर बेसिक विद्यालय
दौलत गंज
लखनऊ (उ.प्र.)

31. श्रीमती स्निग्धा चंद्रा
एयर फोर्स बाल भारती स्कूल
लोधी रोड़
नई दिल्ली

32. श्रीमती चावला
एयर फोर्स बाल भारती स्कूल
लोधी रोड़
नई दिल्ली

33. श्रीमती दीपिका गुरनानी
एन.डी.एम.सी. जूनियर नवयुग स्कूल
लक्ष्मी बाई नगर
नई दिल्ली

34. श्रीमती प्रोमिला मदान
भारतीय विद्या भवन
कस्तूरबा गांधी रोड़
नई दिल्ली

35. श्रीमती राधिका माथुर
दिल्ली पब्लिक स्कूल
वसन्त विहार
नई दिल्ली

36. श्रीमती जया मेहता
मदर इंटरनेशनल स्कूल
श्री अरविन्द मार्ग
नई दिल्ली

37. श्रीमती उमा पुरी
मदर इंटरनेशनल स्कूल
श्री अरविन्द मार्ग
नई दिल्ली

38. श्री सरोजा रामचन्द्रन
दिल्ली पब्लिक स्कूल
वसन्त विहार
नई दिल्ली

39. कु. पद्मिनि शंकर
भारतीय विद्या भवन
कस्तूरबा गांधी रोड़
नई दिल्ली

40. श्रीमती वेला शर्मा
एयर फोर्स बाल भारती स्कूल
लोधी रोड़
नई दिल्ली

41. श्री इंदू बाला शर्मा
एन.डी.एम.सी. जूनियर नवयुग स्कूल
लक्ष्मी बाई नगर
नई दिल्ली

42. श्रीमती वीना यादव
मदर इंटरनेशनल स्कूल
श्री अरविन्द मार्ग
नई दिल्ली

*Fig 88A (left) Early Ordovician (Mid-Canadian) paleogeography Land areas lightly shaded, shallow seas deeply shaded, deep sea horizontally lined Present outcrops are in solid black*

*Fig 88B (right) Middle Ordovician (Black River-Trentonian) paleogeography of North America Symbols as above Clouds are used to hide areas of uncertainty and have no climatic implications*

*Fig 88C (left) Late Ordovician (Richmondian) paleogeography of North America Symbols as above The largely nonmarine part of the Queenston delta is distinctly shaded*

# CHAPTER 8

# THE ORDOVICIAN PERIOD

"Yes, small in size were most created things
And shells and corallines the chief of these"
—T A CONRAD

## PHYSICAL HISTORY OF NORTH AMERICA

**Greatest of All Submergences.** The post-Cambrian emergence was only temporary The continent still lay but little above sealevel, and the Ordovician submergence brought marine waters creeping in over the lowlands from east, west, north, and south in shallow epeiric seas that first flooded the geosynclines and eventually spread over much of the interior, covering at the maximum fully half of the present continent and reducing it to a group of great islands almost awash with the sea (Fig 88C) No other submergence has been quite so extensive in North America

Because of the flatness of the continent, slight local warping greatly altered the outlines of the shallow epeiric seas, a few feet of depression producing embayments of considerable extent, and slight uplift transforming great areas of the shallow sea floor into land As a result, the shorelines shifted back and forth over the interior of the continent, and the paleogeography is very complicated in its details Many maps would be required to present truthfully the slow ebb and flow of these marine floods The three maps here presented (Fig 88) indicate but three temporary stages in an ever-changing scene Each shows a time of main submergence in a distinct epoch

The early Ordovician seas entered the geosynclines first and there left an imposing record of thick limestones and dolomites, but the marine waters also spilled over and at times spread widely across the central and eastern part of the United States

The greatest submergence came during the latter part of the Late Ordovician, when a vast sea spread southward from the Arctic across central Canada to join the southern embayments that occupied much of the United States During this time Appalachia was steadily rising

into mountains, and at the end of the period the northern part, at least, was strongly thrust westward as the *Taconian disturbance* reached its culmination As a result of this uplift and the consequent rapid erosion, the Appalachian geosyncline was filled with sands, muds, and gravel, and in the vicinity of New York and Pennsylvania a vast delta (*Queenston delta*) grew westward until it crowded back the shoreline to a point west of modern Niagara Falls (Figs 88C, 99)

**Four Stable "Domes."** In the midst of these extensive seaways four relatively small areas stood out as persistent lands These were (1) the *Ozark dome* of southeastern Missouri, (2) the *Highlands of*

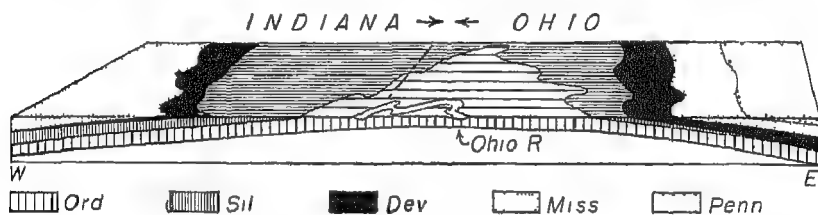



FIG 89 Block diagram showing in its front face a west-east section across the Cincinnati arch near Cincinnati, Ohio Length of section about 215 miles, vertical scale about 8 times the horizontal Adapted from a section by G D Hubbard

*Wisconsin*, (3) the *Adirondack dome* of northeastern New York, and (4) the *Cincinnati arch*, with its southern extremity sometimes distinguished as the *Nashville dome* From the viewpoint of isostasy, each was a positive area tending to rise slightly as the surrounding regions subsided Although none reached mountainous heights, all persisted as landmarks throughout most of Paleozoic time, flanked about by successive epeiric seas They are now areas of relatively ancient rocks encircled by younger strata that dip gently away from the central area, and for this reason they are spoken of as *domes* or *arches* (Figs 89, 81)

The most significant of the four was the *Cincinnati arch*, which ran northward from the vicinity of Nashville, Tennessee, through Cincinnati and western Lake Erie into Ontario, thus paralleling the western side of the Appalachian geosyncline At many times during the Paleozoic era it served as a barrier separating the Appalachian seaways from those farther west Even when partly submerged, it formed a threshold to limit the westward spread of detrital sediments derived from Appalachia

The Cincinnati arch was never mountainous, or even a highland (Fig 89), and it seems remarkable that a structure so broad and low

should have been so persistent. It began to form during the Middle Ordovician, was definitely outlined in the Silurian, and was further elevated at different times during the remainder of the Paleozoic era.

**Temporary Emergences and the Subdivisions of the Period.** Twice during the period there was gentle but apparently complete emergence of the continent. During these intervals the freshly formed sediments were exposed to erosion and locally more or less widely removed, though no folding or pronounced uplift distorted the exposed beds. At the same time there was crowding of the marine invertebrates upon the shallow continental shelves and more or less rapid evolution as diverse emigrants from the epeiric seas were driven into competition. As a result, the following submergence in each instance brought into the new seaways immigrant faunas in which the species and many of the genera were unlike those of the previous invasion. Thus, as in the Cambrian, the Ordovician system of formations is divisible into three series, each separated from the next by a widespread (though not prolonged) stratigraphic break, and each marked by distinctive faunas.

The Early Ordovician has been named the *Canadian epoch* for exposures in extreme southeastern Canada, the Middle Ordovician is known as the *Champlainian epoch* for its striking development along the Champlain Valley, and the Late Ordovician has been called the *Cincinnatian epoch* for exposures about Cincinnati, Ohio.

The system is exceptionally well displayed in New York State, where it was first comprehensively studied and classified. The succession of formations there exposed is therefore regarded as the *type* or *standard section*, with which others in America are compared. From this region also many of the Ordovician names are derived.

**Taconian Disturbance and the Close of the Period.** During the Ordovician period Appalachia was rising again, at first slowly and then with acceleration. This, the *Taconian disturbance*, culminated at the close of the period in a chain of fold mountains that extended from Newfoundland through the Maritime Provinces of Canada and New England and reached at least as far south as New Jersey. It resulted in close folding and westward overthrusting of the older rocks that now occupy a disturbed belt along the south side of the St. Lawrence and the east side of the Hudson Valley (Fig. 90). Remnants of such overthrusts may still be seen in the Taconic Range of eastern New York and in the shale belt of eastern Pennsylvania to the northeast of Harrisburg.[1] Sir William Logan long ago recognized that a great thrust fault follows the St. Lawrence Valley, separating

the intensely deformed rocks of its south shore from the relatively undisturbed ones on the north side. This dislocation has since become known as *Logan's line* It was the locus of late Ordovician overthrusting (Fig 90)

The disturbance began early in the period with local warping in northern Vermont and spread northeastward into Quebec and New-

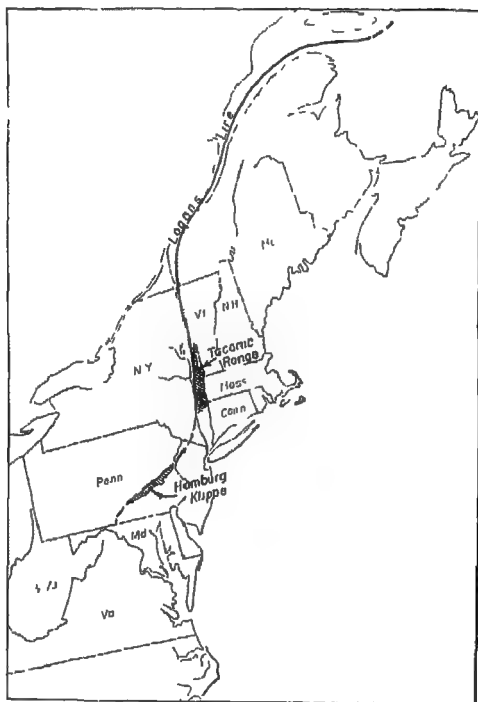



Fig 90 Logan's Line, to the east of which the Ordovician and older strata are intensely deformed The modern Taconic Range is a remnant of a late Ordovician thrust sheet, and the Hamburg Klippe is believed to be a southern remnant of similar origin Data from E B Knopf and from George W Stose.

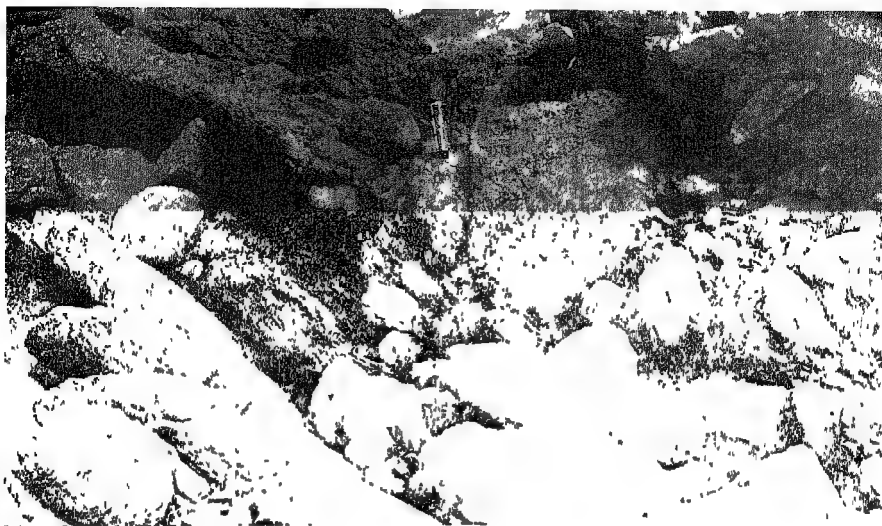
foundland, where submarine thrust faulting gave rise to talus and landslide deposits on the sea floor, these deposits are now preserved as limestone breccias, locally of great thickness and of remarkable coarseness, embedded in dark shales (Fig 91) The regional uplift in northern Appalachia stimulated erosion and resulted in an enormous volume of detrital sediment being carried into the geosyncline During the Early Ordovician, these sediments were mostly fine dark muds, but as uplift continued, they included more and more sand and

CARL O DUNBAR

*Fig 91 Cow Head breccia, a talus deposit resulting from submarine thrust faulting during Ordovician time Cow Head Island, western Newfoundland Hammer above center gives the scale*

gravel and finally culminated in thick sandstones and conglomerates of Late Ordovician age that spread widely over areas where limestone had previously been forming

This *first generation* of Appalachians no longer exists as mountains The highest peaks disappeared through erosion before half a geologic period had passed, and the late Silurian sea advanced over the peneplaned folds, but a record was left in (1) the unconformity between Ordovician and younger rocks in the disturbed area and (2) the coarse detrital sediments deposited in the geosyncline

Most of New England and Maritime Canada suffered two later disturbances, one in the Devonian and another in the Permian, and these largely mask the results of the Taconian disturbance, but in several places along the western margin of the disturbed belt, Ordovician formations can still be seen in folds truncated by erosion and overlain with striking unconformity by Silurian or younger beds Fine examples may be observed along the Hudson Valley from Kingston to Catskill (Figs 92 and 93) In eastern Quebec (Gaspé), also, the Ordovician formations are much more metamorphosed and deformed than the Silurian and commonly are overlain by the latter with angular discordance These relations are well shown in the Matapedia Valley and farther east along the Bay of Chaleur

**Volcanic Activity.** The Taconian disturbance was accompanied by volcanic activity, the first recorded in this region since before the Cambrian Local volcanoes were in eruption in early Middle Ordovician time, spreading ash falls over the Appalachian geosyncline from Alabama to New York, and even as far west as Wisconsin, Minnesota, and Iowa[1] In central Pennsylvania, ten such ash beds have been recognized, intercalated in Middle Ordovician marine limestones (four in the Black River group and six in the Trenton group),[2] and in Alabama two are recognized The ash beds vary in thickness up to more than 7 feet but commonly are only a few inches thick A basic lava flow is associated with one of the ash beds near Jonestown, Pennsylvania,[3] and pillow lava occurs in Middle Ordovician shales at Stark's Knob in eastern New York, the greatest display of volcanic activity, however, is found farther to the northeast, in Quebec and Newfoundland In the Bay of Chaleur region of eastern Quebec, the *Mictaw group* is made up of shales and volcanic tuff of great but undeter-

C R LONGWELL

*Fig 92 Unconformable contact of Upper Silurian (Manlius) limestone on Middle Ordovician (Hudson River) shale at the Alsen quarry, south of Catskill, New York The Silurian beds strike N 35° E and dip 20° NW, whereas the Ordovician beds strike N 5° E and dip 55° E*

CARL O DUNBAR

*Fig 93 Unconformable contact of Upper Silurian (Manlius) limestone on closely folded Middle Ordovician (Hudson River) shale at Becraft Mountain near Hudson, New York White dots follow the contact Dip and strike symbols in white show structure at two places where the shale is crumpled and closely folded*

mined thickness Eastern Newfoundland has tuff and pillow lavas interbedded with graptolite shales and fossiliferous limestones of Middle Ordovician age, and such volcanic rocks spread widely across the center of the island Pillow lavas and agglomerate of great thickness are associated with the Ordovician sediments from Bay of Islands south to Port au Port Bay on the west coast of Newfoundland (Fig 94).

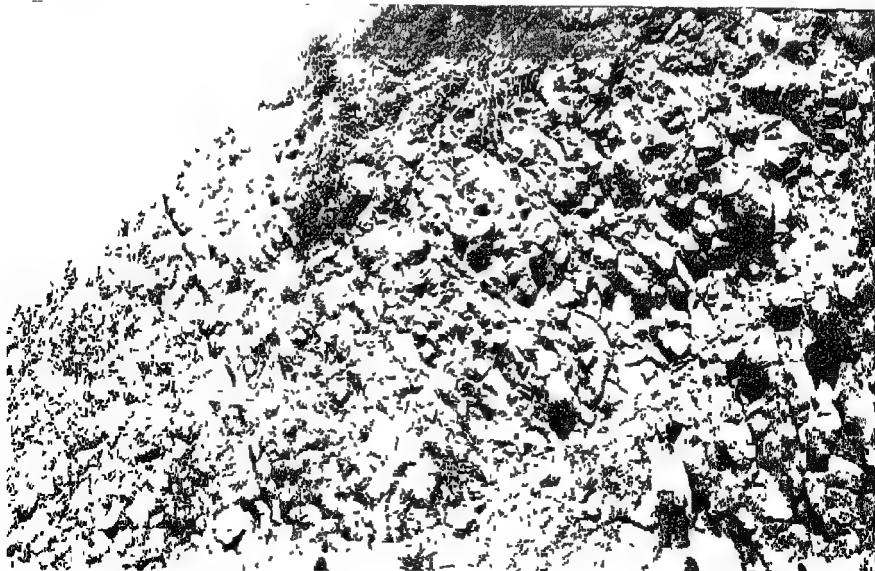
## Climate

Few species of animals or plants now range from southern United States into Canada, and probably none save man and his dog range from the subtropics into arctic latitudes Alligators and palms do not live in Greenland, nor musk-ox and walrus in Florida, for each is imprisoned by the limits of a definite climatic belt. Ordovician

faunas, however, show little regard for latitude, many of the same species occurring in Kentucky, southern Ontario, the Mackenzie Valley, and northern Greenland. In the Upper Ordovician limestones there are small coral reefs widely distributed throughout arctic Canada, from Manitoba to Alaska and northern Greenland, all made of a few common species some of which occur also in Wyoming and New Mexico. We can not escape the conclusion, therefore, that climatic zones were less marked then than now, and that arctic America was not ice-bound at that time. The wide distribution of vast limestones and dolomites bears the same implication, for if parts of the oceans had been much warmer than others, they would have been the chief places of limestone deposition.

Tillites in the Varangerfjord region of northern Norway, long thought to be probably of Ordovician age, are now known to be probably Pre-Cambrian.[1]

CARL O. DUNBAR

*Fig. 94. Pillow lavas interbedded with Middle Ordovician strata near the mouth of Fox Island River, Port au Port Bay, western Newfoundland. The dashed line follows the contact between two flows. The steep dip is due to post-Ordovician deformation.*

## Nature and Distribution of the Ordovician Rocks

**Canadian Formations.** The Lower Ordovician strata present two strikingly different facies (lithologic expressions), the one of dark shale, rich in graptolites, and the other of dolomite with limy-shelled fossils.

The dark-shale facies occurs to the south of the St. Lawrence River all the way from Gaspé to Quebec City and thence southward on both

*Yale Peabody Museum*

Fig. 95. Characteristic four-branched colonies of the graptolite *Tetragraptus* (*Etagraptus*) on a slab of black shale. Lower Ordovician, western Newfoundland. Natural size.

flanks of the Notre Dame and Green mountains through Vermont and eastern New York to New Jersey. It represents the fine dark mud derived from Appalachia and deposited in quiet, stagnant water along the eastern margin of the Appalachian geosyncline. The presence of the four-branched graptolite genus, *Tetragraptus* (Fig. 95), distinguishes it readily from similar but younger shales, and at the same time shows a close connection with similar deposits of the same age in western Europe.

These dark strata are the *Deepkill shales*, so named for a locality in New York but also widely recognized elsewhere in eastern North America. Throughout eastern Quebec they bear a number of interbedded layers or lenses of limestone breccia that have been the object of much speculation. The limestone fragments are angular and show no bedded arrangement or size sorting, yet their fossils indicate that

some were derived from Lower Cambrian formations, others from Upper Cambrian beds, and the majority from Lower Ordovician formations only a little older than the enclosing shales Since the fragments are not rounded, they could not have suffered long transportation, and since they were derived from formations of widely different ages, ordinary erosional processes could not have brought them together In Newfoundland thick and very coarse breccias of this type have been found actually associated with submarine thrust faults where they accumulated as talus or landslide deposits in front of the overthrust masses Probably the breccias in Quebec also owe their origin to thrust faulting, either on the sea floor or in adjacent Appalachia

The Deepkill shale is now limited to the country south and east of *Logan's line* and can not now be traced into calcareous deposits of the same age Immediately to the northwest of this disturbed zone the Lower Ordovician is well developed but in a dolomite facies that extends down the Appalachian trough from Quebec City through the Champlain Valley into New York and Pennsylvania and thence to Virginia and Alabama In this trough it ranges from about 1500 to more than 4000 feet thick and is divisible into numerous formations that bear local names The dolomite is light gray in color and has several peculiarities At various horizons the beds are mud-cracked, indicating that the sea floor was repeatedly exposed In many places thin polygons loosened by the desiccation cracks were swept together by returning currents to form lenses of "edgewise conglomerate" (Fig 96) *Cryptozoon* reefs are very common and widely distributed (Fig 97), but other fossils are as a rule extremely rare There is almost no detrital material Quite clearly it is a marine deposit, yet the water was extremely shallow and the sea floor was frequently exposed over wide areas Similar deposits in Oklahoma, Texas, and New Mexico indicate a remarkable extent of the same peculiar environment In the Ozark region, and from there northward into Minnesota, the Canadian formations are likewise predominantly of dolomite and bear abundant *Cryptozoon* deposits

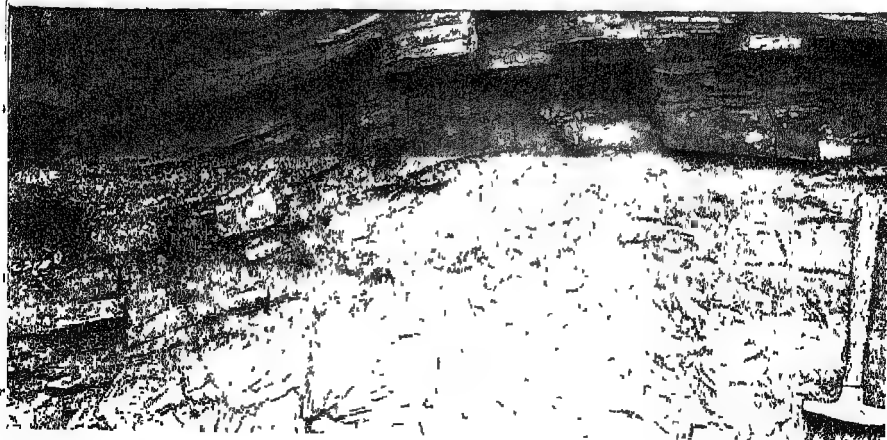
In the Canadian Rockies both the graptolitic and the dolomitic facies are well shown, the latter represented in the center of the geosyncline by cherty limestone and dolomite (Sarbach formation), which, farther west, near the old shoreline of Cascadia, grade over into gray and black shales (Glenogle formation) carrying the *Tetragraptus* fauna

**Post-Canadian Emergence** Nowhere in North America is there any evidence of transition strata from the Canadian into the Champlainian There is a complete break here, which means that the whole continent was dry land for a long time How long can not be told, but the marked difference between the faunas of the Canadian and the Champlainian indicates a considerable lapse of time It is for this reason that some stratigraphers are inclined to regard the Canadian as a distinct period

**Champlainian Formations.** The Middle Ordovician formations generally present a contrast with the rocks below, being mostly limestone and calcareous shale instead of dolomite However, along the eastern border of the old Appalachian geosyncline they also present a black-shale facies all the way from New York to Alabama Local names are used for the whole or various parts of this facies in different regions, but they refer to parts of a continuous belt of dark shales that represents the fine mud eroded from Appalachia and deposited near the shore while limestones were forming farther west This is the lower part of the Martinsburg shale* of the "slate belt" of New Jersey and the central Appalachian region and the equivalent Normanskill and Canajoharie shales of New York

*Black shales of Lower Ordovician age have also been erroneously embraced in the Martinsburg in places in the central Appalachian region

G N KNAPP

*Fig 96 Edgewise conglomerate, a deposit made of thin chips of mud-cracked layers swept together by the currents after a period of emergence Deadwood formation (Upper Cambrian), Black Hills, South Dakota*

Between Albany and Utica, New York, the bluffs of the Mohawk Valley show a complete lateral gradation of black shale (Canajoharie) into the Trenton limestone[5] as represented in Fig 98 To the south in the Appalachian trough the same relation exists between the lower part of the Martinsburg shale and the Mid-Ordovician limestones farther west Since the shales and the limestone interfinger in a broad transition zone, it is evident that they are of the same age and were formed in an open seaway with no barrier between, the mud settling near shore and the purer, limy sediment farther out It is interesting to note that the upper shales spread more and more to the west at the expense of the limestone This reflects the fact that Appalachia was already beginning to rise in Middle Ordovician time and was being stripped of its old mantle, which was being carried into the Appalachian seaway in ever-increasing volume

West of this shale belt the Middle Ordovician is generally limestone throughout eastern United States, tending to pass locally into dolomite in the upper Mississippi Valley Two groups are widely recog-

CARL O DUNBAR

*Fig. 97 Surface of a Cryptozoon reef in the Lower Ordovician dolomite near Port au Port, western Newfoundland The beds have been tilted to the right by post-Ordovician deformation*

nized, the older (Chazyan) being named for classical exposures in the Champlain Valley of New York, and the younger (Mohawkian) for the extensive display along the Mohawk Valley

**Cincinnatian Formations** Throughout eastern United States the Upper Ordovician formations show a further change from limestone to shales and sandstone, reflecting the progressive uplift in Appalachia At the beginning of the epoch mud swept westward as far as Cin-

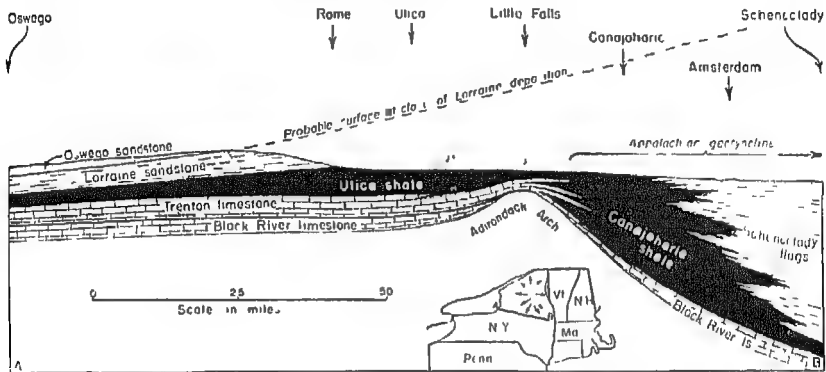



FIG 98 Idealized section across central eastern New York, showing changes of facies in the Middle and Upper Ordovician formations resulting from the growing uplift in Appalachia At this latitude a now-buried extension of the Adirondack arch formed a threshold for a time between the Appalachian geosyncline and the shallow sea floor farther west This ridge was later submerged, and dark muds then spread far to the west As Appalachia continued to rise, sands also spread farther and farther, reaching west of Oswego late in the period Vertical scale greatly exaggerated Data from papers by Marshall Kay

cinnati, forming black shales in the Appalachian trough and bluish calcareous shales farther west While shales and thin-bedded limestone continued to form in the longitude of Cincinnati, the sediments to the east became coarser and coarser, finally passing into conglomerates and nonmarine sandstones

*The Queenston Delta* These higher Ordovician sediments of New York and Pennsylvania represent part of a large delta formed on the west side of Appalachia, as shown in Fig 99 During the first half of the epoch the landward part of the delta was very small, and the sediments were largely, if not entirely, marine As erosion increased in rising Appalachia, however, the shoreline was crowded gradually westward until a low delta plain stretched from the foothills to beyond the region of Niagara As the region of deposition was slowly subsiding, sediments accumulated over the landward front of the delta

as well as over its submerged portion Those in the former region, under the climatic environment then obtaining, were largely oxidized to a red color, while the submarine sediments remained gray Thus the barren, red Queenston shales (now exposed in the base of the lower gorge of Niagara) are contemporaneous with fossiliferous Richmond beds of the Lake Huron and Cincinnati regions Irregular subsidence and building at the delta front caused a to-and-fro migra-

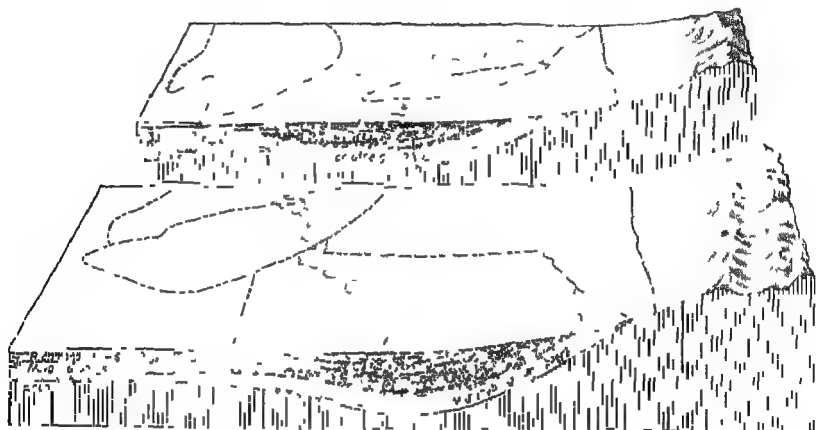



FIG 99 Stereogram of the Queenston delta as it would have appeared at the close of the Ordovician period The view is north across Pennsylvania and New York states and the eastern Great Lakes A part of the old Taconian highland is shown at the extreme right The block has been parted along an east-west cut, and the names of the chief Middle and Late Ordovician formations are indicated on the vertical faces exposed In these sections the nonmarine deposits are in darker shading than their marine equivalents Length of front face, about 600 miles

tion of the shoreline as the deposits grew, and as a result the Queenston and Richmond formations interfinger over a broad transition zone in Ontario

*Dolomites of the Cordilleran and Arctic Regions* Beyond the limits reached by the sediments from Appalachia, the seas were generally clear, for the western lands remained low As a result, the Upper Ordovician is represented throughout the Rocky Mountain region and arctic Canada by a remarkably widespread and homogeneous formation of massive, cliff-forming dolomite In the northern Rockies of the United States, this is known as the Bighorn dolomite It is recognized under local names from northern Mexico to Alaska and northwestern Greenland, and, strangely, over this vast area it seldom exceeds a thickness of 300 feet Its fauna is everywhere much the same, consisting of corals, cephalopods, and large gastropods

## Mineral Resources

**Petroleum and Natural Gas.** The discovery of petroleum, just before the days of the Civil War, marked the beginning of an industry that was destined to change the course of civilization, for it led to the perfection of the internal-combustion engine and made feasible the automobile, the airplane, and other miracles of our modern age

The first oil well was driven in Devonian rocks in Pennsylvania in 1859, and Ohio followed with a "pioneer well" in 1883 that tapped the Trenton limestone at a depth of more than 1000 feet and produced a heavy flow of gas This was followed by the rapid exploitation of a large oil field on the Wabash arch in northwestern Ohio (Lima field) that derived both oil and gas from Middle Ordovician strata Between the years 1886 and 1900 it was one of the major American oil fields, later the production greatly declined, and for some years Ordovician rocks were not important producers.

Since 1920 the Ordovician rocks under the Mid-Continent oil fields have assumed great importance in Oklahoma and northern Texas The earlier production in this region had been from younger strata, chiefly Pennsylvanian, but with deeper drilling the Wilcox sand of Ordovician age has proved to be the greatest producer in the region, and in several fields, such as that of the Oklahoma City pool, has given rise to spectacular gushers and phenomenal production

**Building Stone.** Most of the *slate* produced in America comes from the great shale belt of Ordovician rocks discussed above The fine muds spread here in Ordovician time were in places so squeezed and metamorphosed by later disturbances that they developed a perfect slaty cleavage The thicker and more homogeneous beds are quarried and split into shingles for roofing or slabs for electrical switchboards or for other industrial uses A very large proportion (about 80 per cent) of the material quarried is not suitable for the market, and the mountainous piles of refuse in the slate belt form an imposing monument to the industry The chief producing states are Pennsylvania, Vermont, New York, and Virginia In 1939 more than 531,380 tons of slate were produced, with a market value in excess of $6,680,000. More than nine-tenths of this slate was of Ordovician age During the war years the use of roofing slate declined, but industrial uses increased, the total value in 1945 being over $5,658,000

*Limestones* and *dolomites* of Ordovician and Late Cambrian age, widely spread in the great Appalachian Valley, serve so many uses

that their aggregate value would be difficult to estimate Besides furnishing constructional stone for local use, they are crushed for road metal, burnt for lime to use as fertilizer, whitewash, or mortar, used for flux in the reduction of iron ores, or mixed with shales in the manufacture of cement

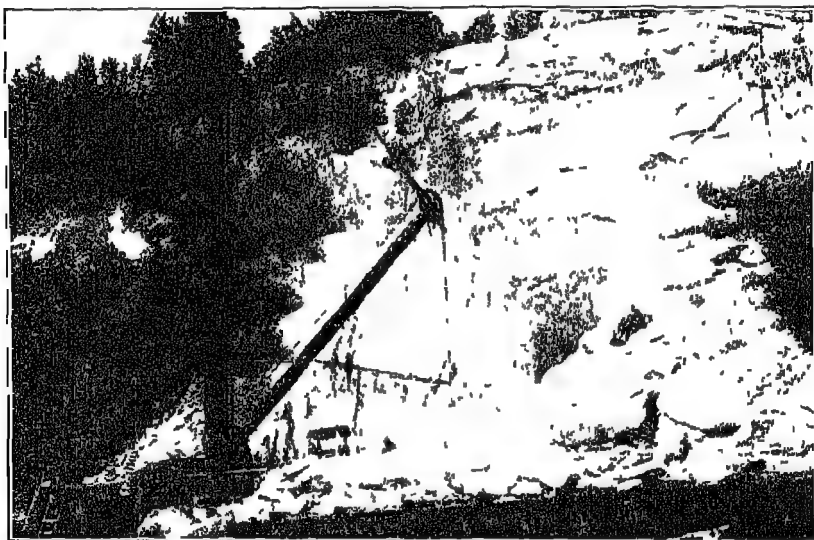
It is a striking fact that most of the *marble* quarried in the United States for interior decoration and finish trim is of Ordovician age

*C R Longwell*

FIG 100 Entrance to a marble quarry at Proctor, Vermont Similar quarries in this region follow steeply dipping beds of pure marble to depths as great as 300 feet The age of this marble is early Middle Ordovician (Chazyan)

The greatest quarries are near Rutland, in south-central Vermont, where immense underground mines produce most of the "American Carrara" (Figs 100, 101) Although the stone is of Ordovician age, its metamorphism from limestone to marble was accomplished by orogeny that came later Pink and deep red "marbles" for decorative interior finish are secured from the Middle Ordovician of eastern Tennessee, and black "marble" is quarried from nearly equivalent rocks on Isle Lamotte in Lake Champlain Very fine marble is also quarried from Ordovician rocks near Yule, Colorado The annual production of the Ordovician marbles in normal prewar years exceeded $5,000,000 in value.

**Ore Deposits** No important metalliferous deposits of Ordovician age are known in America except the sedimentary iron ore of Belle Isle in eastern Newfoundland Here the Lower Ordovician strata include six zones of red oolitic hematite that range from a few inches to 50 feet in thickness The mines now extend under the sea The annual output averages over 1,000,000 tons

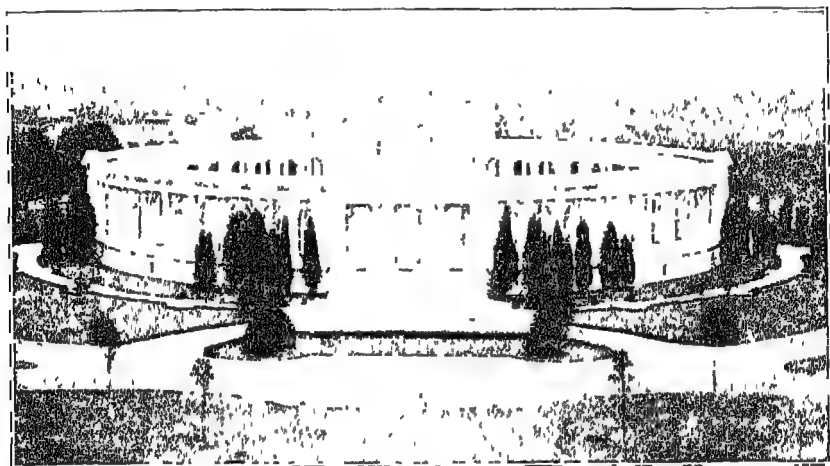
Lead and zinc ores occur in the Middle Ordovician dolomite in Wisconsin and northwestern Illinois, but since they were formed dur-

*Vermont Marble Company*

Fig 101 Arlington Memorial Amphitheatre in the national cemetery near Washington, D C, the world's largest cemetery monument, constructed of Vermont marble

ing a later geologic age, they hardly deserve discussion in the history of this period

## Life of Ordovician Time

**Primitive Fishes, a Prophecy of Higher Types of Life.** The shallow seas remained the chief arena of life as another geologic period stretched to a close, for the Ordovician has yielded no proved record of either land animals or land plants At three widely spaced localities in the Cordilleran region, however, middle Champlainian * rocks bear the petrified bony armor plates of very primitive fishes The first

* Although long regarded as Middle Ordovician (Black River) (Kirk, 1930), this horizon may prove to be of Late Ordovician (Richmond) age Further investigation is needed

locality to be discovered is in the Harding sandstone near Canyon City, Colorado, whence Walcott announced the finding of fish remains in 1891 The same horizon has since yielded similar fossils in the Big Horn Mountains and in the Black Hills In all three localities the bony plates are very fragmentary and show little of the size or character of their owners, but a comparison with well-preserved remains found elsewhere in Late Silurian and Devonian rocks shows clearly that they represent the order of fishes known as the *Ostracoderma* (Figs 102 and 103) Strange as these fish look, they are yet related to living hagfishes (cyclostomes) From their fragmental nature and their occurrence in cross-bedded sandstone, it seems probable that they inhabited fresh waters, and after death were drifted by the rivers and broken up before arriving in the marine sediments of the littoral zone As the most ancient relic of vertebrate life they foretell the coming dominance of higher animals—a prophecy that had to wait another geologic period for its fulfilment!

*W L Bryant*

FIG 102 Fragment of the bony armor plate of the oldest known fish, *Astraspis desiderata*, from the Harding sandstone at Canyon City, Colorado Natural size

**Continued Dominance of Marine Invertebrates** The shallow marine waters of Ordovician times swarmed with a rich variety of invertebrate animals Although the stocks represented in the Cambrian still held the field, a number of new classes sprang rapidly into prominence, notably the graptolites, true corals, crinoids, bryozoa, and clams

The dolomites so widely formed during Early Ordovician time lost the majority of their fossils during deposition as a result of the diagenetic change from calcareous to dolomitic sediment In the dolomites the fossils most commonly seen are thick-shelled gastropods and cephalopods and *Cryptozoon* algal reefs

The widespread, limy formations of the Middle Ordovician contain a more complete record of contemporaneous life than any other group of the Paleozoic rocks More than 2600 species are known from the Champlainian rocks of North America alone The host of bryozoans

limy-shelled brachiopods, and crinoids leaves a striking impress on these faunas Cephalopods and trilobites still held a prominent position, and the first true corals made their appearance During this epoch a straight-shelled cephalopod, *Endoceras proteiforme*, attained the greatest size of any creature of the early Paleozoic world, its chambered shell exceeding a length of 15 feet with a diameter at the front of about 10 inches (Fig 101)

The Upper Ordovician faunas resemble those of the Champlainian in general features, though they are neither so prolific nor so abundant in the muddy and sandy formations of the Appalachian trough nor in the dolomites of the West and the North In the Cincinnati region, however, the profusion and wonderful preservation of the Late Ordovician life have been an inspiration to amateur collectors and professional geologists as well

Fig 103 An ostracoderm fish, *Drepanaspis gemundenensis*, from the Lower Devonian of Germany Length, about 9 inches The Ordovician genus, *Astraspis*, is believed to have resembled this Devonian fish From Patten

**Geographical Restrictions of the Faunas** *Faunal realms* and *provinces* existed in Ordovician time as in the Cambrian or the Present, each of the oceans having certain genera and species of its own, notwithstanding a world-wide similarity in the types of life It is possible thus to distinguish embayments of Atlantic, Arctic, or Pacific source Some of the faunas of extreme eastern North America likewise show much closer affinity to faunas of Europe than to those of interior North America, which were closer geographically but occupied a distinct embayment Of course, when the interior seas became as extensive as they were in Middle and Late Ordovician time, the animals from different provinces could migrate and mingle freely until the faunas became nearly cosmopolitan

Another type of faunal restriction is seen in the striking contrast between contemporaneous faunas of black shale and limestone The black shales are the deposits of foul, stagnant mud bottoms upon which but few types of animals could live As a result their fossils are chiefly the floating graptolites, along with small phosphatic brachio-

pods (Neotremata) which may have been attached to seaweed, the mud-loving brachiopod *Lingula,* and the chambered shells of cephalopods which probably floated after death Certain types of trilobites are also abundant On the other hand, we find here none of the corals, bryozoa, limy-shelled brachiopods, clams, or gastropods which dwelled of necessity upon a solider and cleaner sea floor and which made up the faunas now preserved in the limestones and calcareous shales

*Chicago Natural History Museum*

FIG 104 An Ordovician sea beach, on which specimens of the great cephalopod, *Endoceras,* are stranded From a painting by Charles R Knight.

This should not be surprising, for the modern sea floors show equally marked local faunas separated only by differences in the bottom environment The Bay of Naples, for example, includes a limy shoal known as "Pigeon Bank" which is surrounded by slightly deeper water with a soft mud bottom Here there are known 341 species of shell-bearing invertebrates (capable of fossilization) of which 296 are restricted to the limy shoal and 31 to the mud bottom An additional 14 species live on both [6] A group of animals adapted thus to life on a restricted type of sea floor will, of course, be limited to a distinct type or facies of the sediments and is therefore known as a *facies fauna* It is evident that the fauna of a Lower Ordovician black shale will

show more general resemblance to that of another black shale of Middle or Upper Ordovician age than to a limestone fauna of its own time Only the interfingering of the faunas and the sediments where one grades laterally into the other will show the equivalence of dissimilar but contemporaneous facies faunas

**Résumé of the Invertebrate Hosts.** Neither Protozoa nor sponges are important in the Ordovician rocks, though both are represented

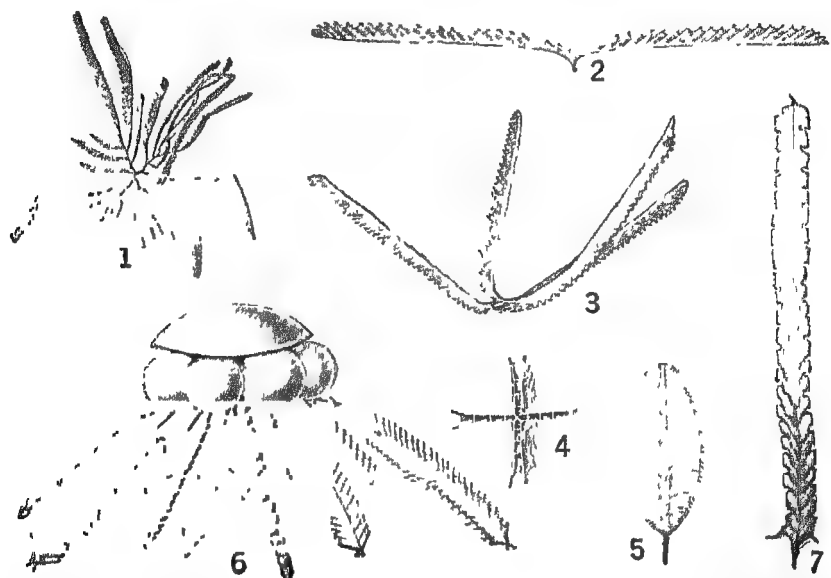



Fig 105 Ordovician graptolites 1, *Clonograptus flexilis*, a colony of many branches, 2, *Didymograptus nitidus*, a two-branched colony, 3, *Tetragraptus serra*, a four-branched colony, 4, 5, *Phyllograptus typus*, cross-section of one colony and side view of another flattened in the shales, 6, *Diplograptus pristis*, a colony with floating bell and reproductive pouches, 7, *Climacograptus modestus* (lower part normal, upper flattened) Natural size

The most distinctive animals of the time were the *graptolites*, which became immensely common at the very beginning of the period (Fig 105) The majority of these were floating creatures, and therefore of world-wide distribution, drifting freely across the open oceans *Phyllograptus* and *Tetragraptus*, the distinctive genera of the Lower Ordovician black shales, have been found in Canada, the United States, Scandinavia, Wales, Belgium, France, Peru, Bolivia, Australia, and New Zealand Successive zones characterized by different generic types are of widespread occurrence and form one of our most exact means of determining the equivalence of rocks in widely separated regions

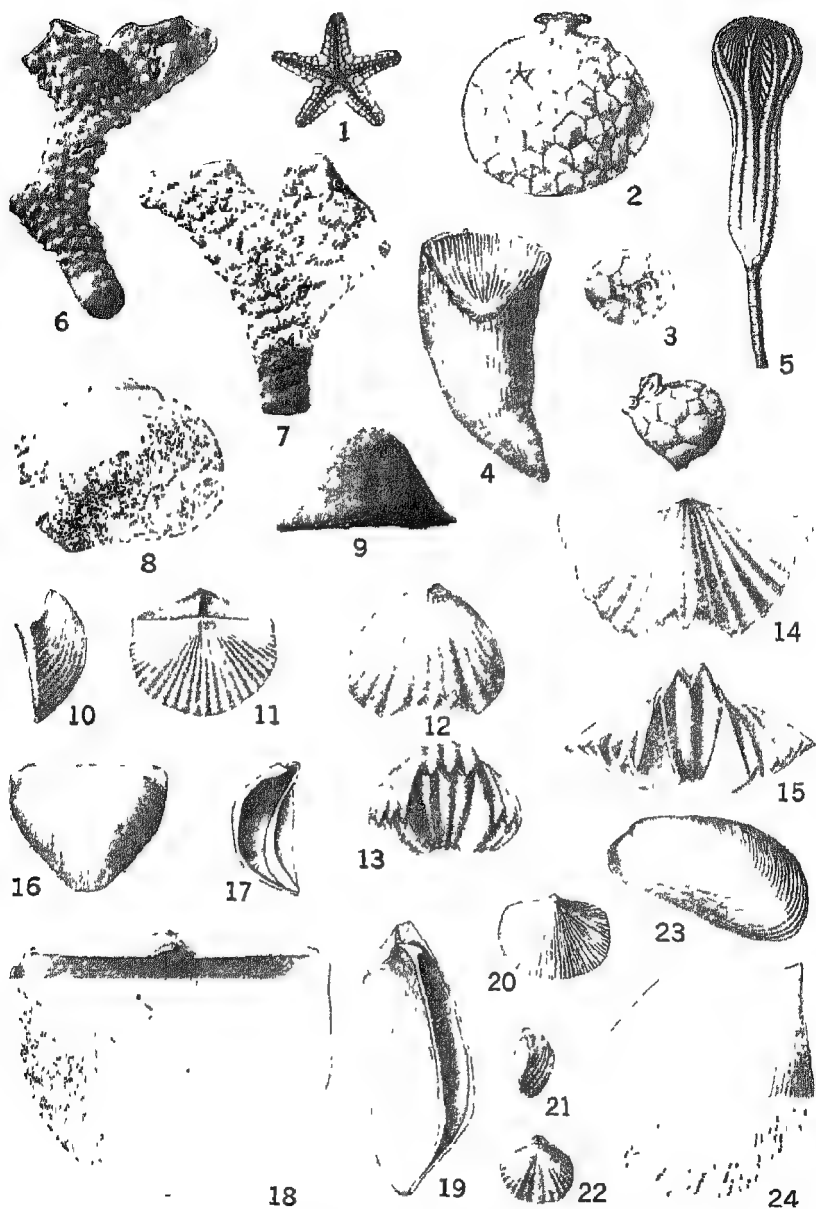



Plate 4 Ordovician Echinoderms (1–3, 5), Coral (4), Bryozoa (6–9), Brachiopods (10–22), and Pelecypods (23–24)

Fig 1, *Hudsonaster narrawayi*, one of the oldest known starfish, 2, 3, the cystoids *Echinosphaerites aurantium* and *Malocystites emmonsi* (upper and side views), 4, *Streptelasma rusticum*, 5, the crinoid *Ectenocrinus grandis*, 6, *Hallopora ramosa* (fragment of a stemlike colony), 7, *Constellaria florida*, 8, 9, *Prasopora simulatrix* (summit and lateral views), 10, 11, *Hesperorthis tricenaria*, 12, 13, *Rhynchotrema capax*, 14, 15, *Platystrophia laticosta*, 16, 17, *Strophomena nutans*, 18, 19, *Rafinesquina alternata* (19, section to show

True *corals* appeared near the very base of the Middle Ordovician series A primitive honeycomb (*Lamottia*) formed low reefs as much as 100 feet across, now shown in the Chazy limestone on Isle Lamotte in Lake Champlain A small, simple horn coral (*Lambeophyllum*) occurs a little higher, associated with small heads of a compound coral (*Foerstephyllum*). There are but a few species, however, though small reefs are widely distributed in the Late Ordovician strata

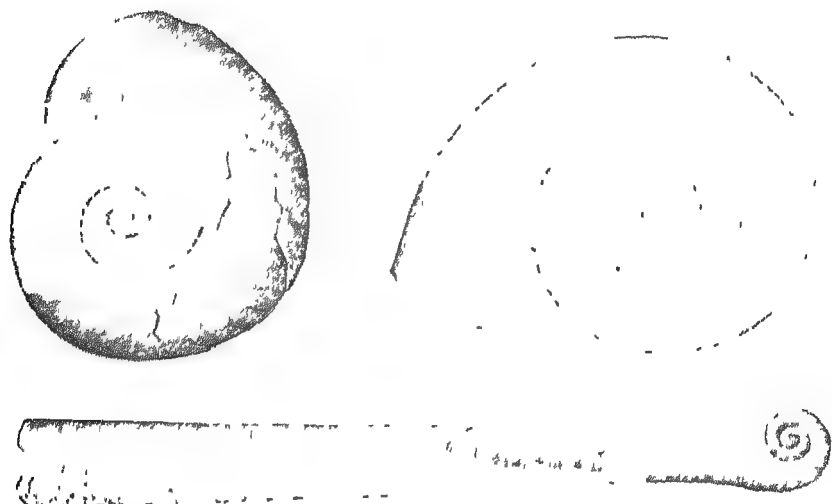



Fig 100 Ordovician cephalopods Upper left, *Plectoceras occidentale*, upper right, *Schroederoceras eatoni*, lower, *Lituites lituus* In each specimen a part of the shell is broken away to show the sutures on the internal mold Natural size

*Bryozoa* (Pl 4, figs 6–9) made their first appearance near the base of the Ordovician but expanded into great variety in the middle and upper part of the system Probably 1000 kinds are present in the rocks of the Champlainian series alone

*Brachiopods* (Pl 4, figs 10–22) likewise experienced a rapid evolution, especially those with limy shells, though the primitive types with corneous or phosphatic shells which had been so prominent in the Cambrian declined rapidly The majority of the brachiopods were now "square-shouldered" and almost all had radially striate or ribbed shells Only a very few had calcareous gill supports in the form of spiralia.

*Echinoderms* were represented by a variety of *cystoids* and by numerous *crinoids*, along with the first rare *starfish* and the earliest known *blastoids* (Protoblastoidea) (Pl 4, figs 1–3,5).

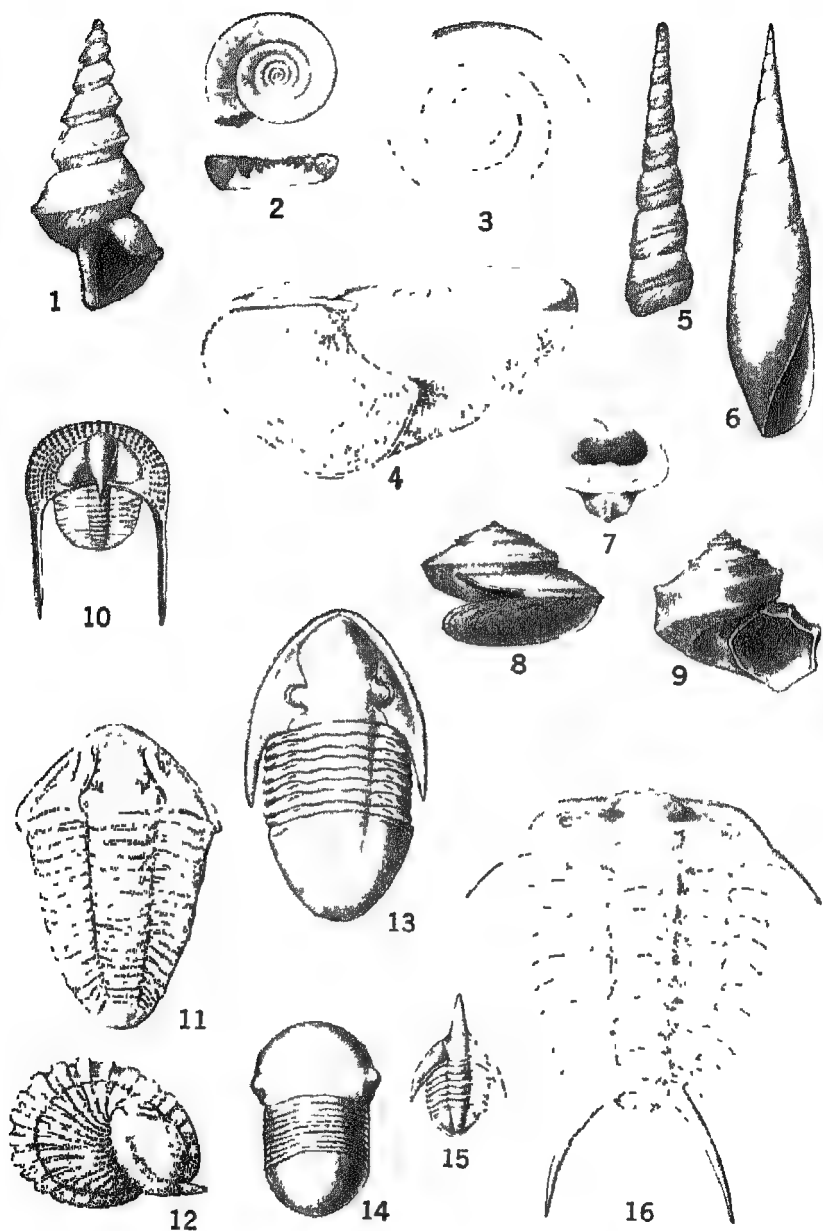



Plate 5 Ordovician Gastropods (1–9) and Trilobites (10–16)

Fig 1, *Lophospira bowdeni*, 2, *Lecanospira compacta*, 3, *Ophileta grandis*, 4, *Maclurites logani* (with operculum), 5, *Hormotoma artemesia*, 6, *Subulites canadensis*, 7, *Bellerophon troosti*, 8, *Eotomaria supracingulata*, 9, *Trochonema umbilicatum*, 10, *Cryptolithus tessellatus*, 11, 12, *Calymene meeki* (dorsal view in crawling position, and side view enrolled), 13, *Isotelus gigas*, 14, *Bumastus trentonensis*, 15, *Ampyx nasutus*, 16, *Ceraurus pleurexanthemus* All natural size Drawn by L. S. Douglass

*Gastropods* (Pl 5, figs 1–9) showed a surprising evolution into probably as many species as there were of brachiopods, though they were as a rule not so abundant individually as the latter, nor so well preserved Species with low, widely coiled shells greatly predominated, but many had already attained high graceful spires

*Clams* are exceedingly rare until we come to the Champlainian and are first abundant and widely spread in the sandy formations of the Upper Ordovician of the Appalachian trough (Pl 4, figs 23–24)

Fig 107 Ostracods on the surface of a slab of Middle Ordovician limestone About ½ natural size

*Cephalopods* (Figs 104, 106) are represented by both straight and loosely coiled shells in great variety, the former including a number of species of large size As a class, these were the largest invertebrates of their time.

*Trilobites* (Pl 5, figs 10–16) were still exceedingly numerous and varied, probably attaining the climax of their evolution during this period If we may judge by their varied form, they were adapted to a wide range of conditions. One striking trend of the times is seen in two of the commonest families, which tended to lose the trilobation of their carapace and the marks of segmentation in both head and tail shields, giving rise to "bald-headed" types like *Bumastus* and *Isotelus* (Pl 5, figs. 13, 14) The little groveler, *Cryptolithus*, with its pitted frill (Pl 5, fig 10), is very characteristic of Ordovician time

Finally, we must note the first occurrence of the *Ostracoda*, minute crustaceans with bean-shaped, bivalved shells completely enclosing the body as do those of small clams (Fig 107)

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## Chapter 9

# THE SILURIAN PERIOD

**Founding of the Silurian System.** Before 1830 the geologic succession was unknown below the "Old Red" sandstone that underlies the Coal Measures of England. The older rocks were then looked upon as a chaos of deformed and nearly unfossiliferous beds holding little promise that a clear sequence could ever be determined. To their solution there came a remarkable young Scotsman, Roderick Impey Murchison (Fig. 108), whose rise to fame began with his recognition of the Silurian system.

Fig. 108. Sir Roderick Impey Murchison (1792–1871).

After 6 years in public school and 2 at a military academy he joined the army at the age of 15 and served through the Napoleonic wars. With the return of peace he retired to his estate in the northwest highlands of Scotland to become a gentleman of leisure. Fortunately he soon came under the influence of Sir Humphry Davy, who persuaded him to go to London and take courses in chemistry and allied subjects. There the lectures in geology aroused in him an interest that was fanned into enthusiasm as he tramped the hills in company with two of the foremost geologists of the day, William Buckland of Oxford and Adam Sedgwick of Cambridge. At the age of 32 he set himself the task of reading and gaining a self-made education in geology. His spectacular rise from this start to become one of the most distinguished scientists of his time, and, eventually, the director of the Geological Survey of Great Britain, is one of the inspiring chapters in the history of geology.

Murchison's first extensive work was the description of the Silurian system. In 1831 he and Sedgwick resolved to attempt the unraveling

of the "Primitive Series" which lay below the "Old Red" and formed most of the country of Wales. Murchison began his investigations at the base of the Old Red and worked westward (Fig. 109). Here he found that the older rocks, though deformed, were not chaotic but formed a regular succession of gray shales and limestones rich in distinctive fossils. By 1835 he had worked out a succession of thousands of feet of such strata which he defined as a new geologic system.

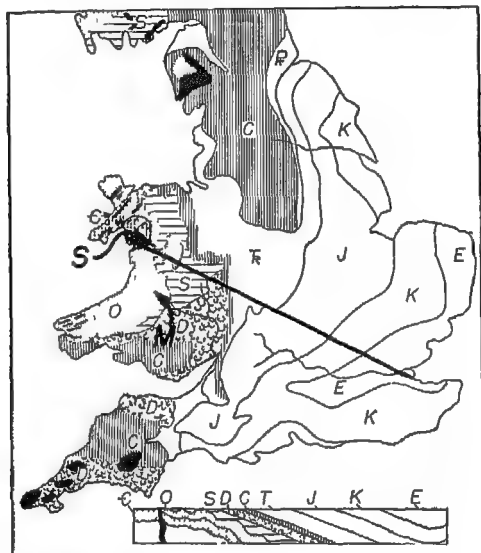



FIG. 109. Geologic map of England and Wales, with cross-section from northwestern Wales to London. Igneous rocks in black. Darts indicate localities where Murchison (*M*) and Sedgwick (*S*) began work on the Silurian and Cambrian systems, respectively.

Seeking a classical name, he called it Silurian after an ancient Celtic tribe (the Silures) which Cæsar's legions had encountered here during the Roman conquest. His great volume, *The Silurian System* (1838), is now a classic in geology.

Sedgwick had meanwhile worked out a great sequence of rocks in the much-disturbed region of northwestern Wales (Fig. 109), and this he simultaneously defined as the Cambrian system. In 1835 both Sedgwick and Murchison supposed the Cambrian system to lie entirely below the Silurian, but as work progressed, it became evident that the two overlapped, and that the lower half of the Silurian was included in the Cambrian. When Sedgwick subsequently showed the presence of an important unconformity in the midst of the Silurian,

Murchison still would not yield, but insisted on restricting the name Cambrian to older and generally unfossiliferous rocks. A bitter controversy ensued which not only estranged these two great pioneers but split the geologists of Europe into two camps for more than a generation

In 1879 Professor Lapworth of Birmingham proposed to cut the Gordian knot by removing the debatable "Lower Silurian" to a distinct system, the *Ordovician,* and after many years of discussion this solution has now received wide acceptance

## Physical History

**Patterns of Land and Sea** As the Silurian period opened, Appalachia was still mountainous, but the rest of North America was almost flat A slow submergence brought shallow seas over much of the eastern United States and over southeastern Canada, as shown in Fig 110*A* Notable differences in the Early Silurian faunas of the northern and southern outcrops indicate that a low barrier south of the Great Lakes region separated a southern embayment from a northern one It is not unlikely that the sea west of Hudson Bay also extended northward to the Arctic (as in Late Ordovician and Middle Silurian epochs), but the evidence for this is not yet clear No submergence is recorded in the western part of the continent, but it is not improbable that southern Alaska was submerged

Marked differences between the Early and Mid-Silurian faunas suggest a temporary emergence after this Early Silurian flood, but, if so, the waters returned shortly and spread to still greater extent during the middle of the period (Fig 110*B*) At this time the eastern part of the continent was again flooded, and embayments entered the western part from the Arctic and the Pacific

A long and nearly complete emergence ensued during Late Silurian time, when only a shrunken remnant of the inland sea covered a part of the central Appalachian states and the Great Lakes region, as shown in Fig 110*C* Thick marine formations accumulated here with immense quantities of salt This sea must have been connected with the ocean, from which fresh sea water flowed to counterbalance evaporation, but the position of this channel is still uncertain It may have been via the northeast to the Atlantic or via the northwest to the embayment that covered the Mackenzie Valley region These possible connections are indicated by broken shading in Fig 110*C*. No outcrops of Late Silurian rocks are known in either direction, but a line

*Fig 110A (left) Early Silurian paleogeography of North America Land areas lightly shaded, shallow seaways deeply shaded, deep sea horizontally lined, present outcrops solid black*

*Fig 110B (right) Middle Silurian paleogeography Symbols as above This shows the maximum Silurian submergence of North America The Taconian Highlands were now much reduced*

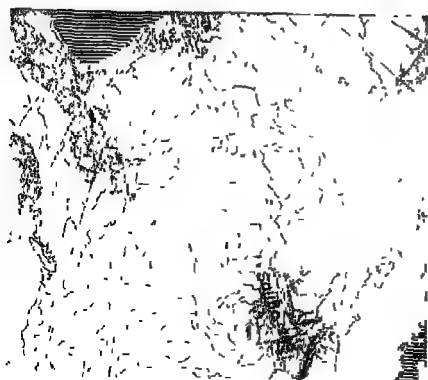



*Fig 110C (left) Late Silurian paleogeography Symbols as above Barred strips to the northwest and northeast of the Salina sea represent problematical connections to the oceans, other symbols as above*

of salt seeps along the edge of the Devonian overlap between Lake Manitoba and Great Slave Lake suggests buried salt beds that may be of Late Silurian age.

The Silurian period is naturally divided into three epochs: the Early Silurian or Medinan[*] epoch (named for the Medina sandstone of New York and its correlatives), the Middle Silurian or Niagaran epoch (named for the record so grandly displayed in the gorge at Niagara Falls), and the Late Silurian or Cayugan epoch (named for the thick salt-bearing strata about Cayuga Lake, New York).

The Pacific embayment that covered the panhandle of Alaska left an exceptionally thick series of fossiliferous limestones. These formations, however, have not yet been adequately studied and classified.

**Local Volcanic Activity.** The northern part of the Appalachian province was again the site of volcanoes which remained active locally during much of Silurian time. Black Cape on the north shore of the Bay of Chaleur, facing the Gulf of St. Lawrence, displays over 4000 feet of black lavas interbedded with Middle Silurian limestones. Apparently the eruptions here were from submarine volcanoes, for the base of the first flow includes fossil coral heads and brachiopods over which the lava flowed. Farther southwest in New Brunswick and especially in southeastern Maine, ash beds and lava flows attain the impressive thickness of 10,000 feet or more. Here and there among these volcanics are strata with marine fossils that prove the Silurian age of the lavas. Lava flows, volcanic breccia, and tuff occur also in the Silurian of southern Alaska and in the Copley formation of probable Silurian age in northern California.[1]

**Quiet Close of the Period in America.** No mountains were made in North America at the close of this period, and the overlying Devonian formations generally lie parallel to the Silurian with little evidence of hiatus. Outside the central Appalachian trough, however, it is usually the Middle Devonian that rests upon the Middle Silurian, since both the Late Silurian and the Early Devonian formations have a very restricted distribution. The relation at the "Beargrass" quarries near Louisville, Kentucky (Fig. 111), is general over the Ohio Valley, where pure Middle Devonian limestone rests disconformably on similar strata of Middle Silurian age. When viewing such an outcrop, it is difficult to realize that in the Appalachian trough sediments

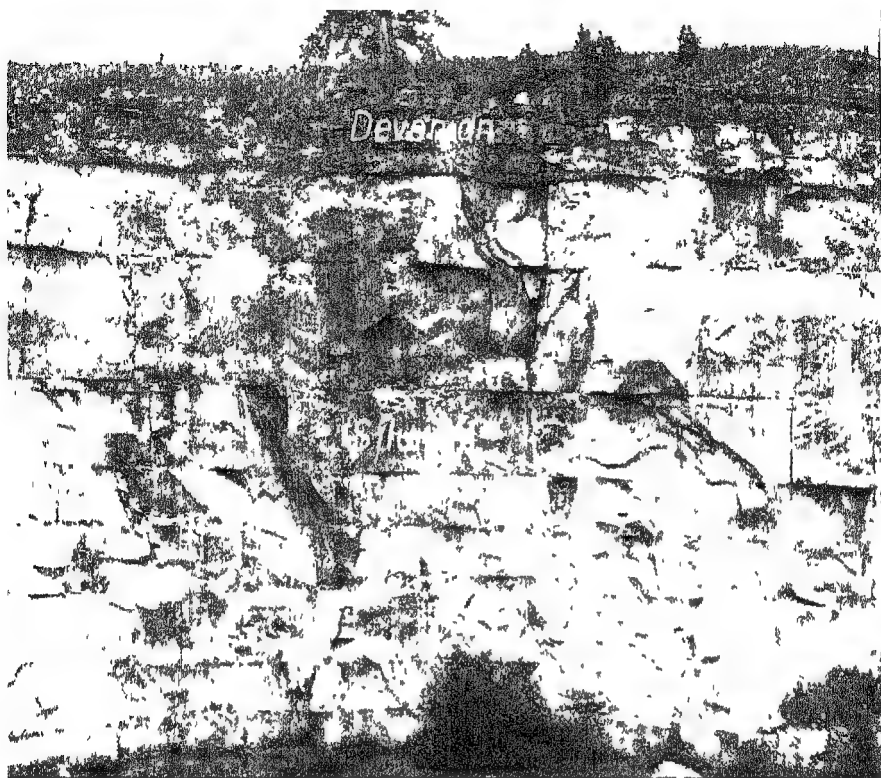
[*] General agreement has not yet been reached as to the best name for the Early Silurian epoch. The name Alexandrian is also in use.

CHARLES SCHUCHERT.

*Fig 111 Disconformable contact of Middle Devonian on Middle Silurian limestones in Beargrass quarries near Louisville, Kentucky The contact is in the midst of the massive bed below the word Devonian*

almost a mile thick were formed during the interval represented here by an irregular bedding plane Obviously the emergent continent lay quiet and but little above sealevel during the long interval

**Caledonian Disturbance of Europe.** In Europe, on the contrary, the close of the Silurian witnessed the rise of the majestic Caledonian Mountains, which ranged northeastward across the British Isles and Scandinavia In Scandinavia the orogenic forces came from the west, folding the Silurian and older formations and carrying them eastward in a series of great thrusts Throughout the length of Norway and Sweden, a distance exceeding 1100 miles, the pre-Devonian formations were folded, overturned, and overthrust with eastward movement on individual fault planes as great as 20 to 40 miles The mountains that crossed Great Britain seem to have been a subparallel range

striking to the west of that in Scandinavia and curiously paired with it, in that here the thrusts were to the west instead of the east If we include the folding in eastern Greenland and Spitzbergen, the Caledonian Mountains can be traced for more than 4000 miles and were undoubtedly one of the great mountain systems of the world (Fig 112)

Another range stretched eastward across northern France and southern Germany into northern Austria, while still other mountains were

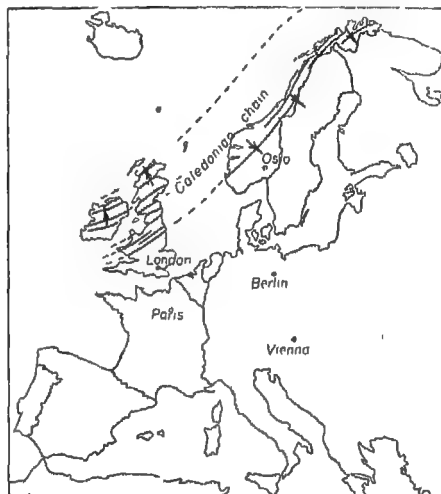



Fig 112 Map showing the location of the Caledonian Mountains of late Silurian date

forming in northern Africa (Oran Sahara) and in north-central Asia (Irkutsk basin of Siberia).

## Stratigraphy of the Silurian Formations

**Influence of the Taconian Range** During Early and Middle Silurian time the Appalachian trough received abundant sandy sediments from the east as the highlands in Appalachia were gradually worn down This material, trapped between Appalachia and the Cincinnati arch, kept the geosyncline silted up to near or above sea-level, oscillating between the condition of shallow sea floor and low coastal plain Along the eastern margin of the geosyncline, pure sandstone and quartz conglomerate stretches all the way from New York to Alabama, attaining a maximum thickness of more than 1000 feet and ranging between this and 500 feet over most of the folded region, where it is one of the chief ridge makers

To the northwest and west the sandstone grades over into shale, but tongues of it reach far to the west, as indicated in Fig 113 Along the eastern margin the sandstone is generally unfossiliferous and

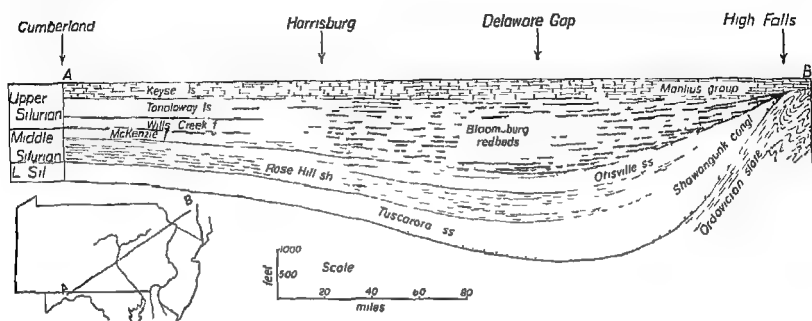



Fig. 113 Section of the Silurian formations between Cumberland, Maryland, and High Falls, New York, showing the influence of the Taconian Range The section runs obliquely across the geosyncline Data from papers by C K and F M Swartz

may have been deposited upon a low coastal plain, but farther west it includes a limited variety of marine fossils, notably ostracods, small clams, and the burrowing brachiopod, *Lingula*

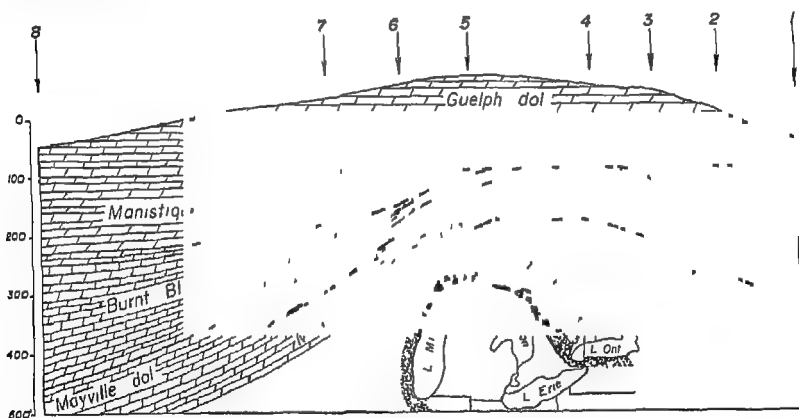



Fig 114 Silurian section along the Niagara cuesta from Medina, New York, to Manistique, Michigan The inset map shows the outcrop belt and the position of the eight numbered localities 1, Medina, New York, 2, Niagara Falls, 3, Hamilton, Ontario, 4, Cataract, 5, Owen Sound, 6, Cabot Head, 7, Manitoulin Island, 8, Manistique, Michigan Vertical scale greatly exaggerated Adapted from E R Cumings

During Early Silurian time the sand spread as a vast, continuous sheet over the geosyncline Several local formation names are used for it (Shawangunk, Medina, Tuscarora, Clinch), but they all refer to

parts of this single vast deposit that records the degradation of the Taconian Range. As shown in Fig. 113, the sand was much more restricted in Middle Silurian time, and from then until nearly the end of the period most of the deposits in the geosyncline were muds. Finally, by Late Silurian time, even muds were more limited, and limestones accumulated over the western half of the geosyncline; as a final episode the sea again spread over the truncated folds along the western edge of the Taconian Range. By this time Appalachia was worn so low that limestone formed as far east as the Hudson Valley (see Figs. 113 and 93).

*Charles Schuchert*

FIG. 115. Cabot Head shale (below) grading upward into Grimsby (=Albion) sandstone, along New York Central Railway in Niagara Gorge. This is a detail of the transition represented in Figs. 114 and 116.

In Gaspé Peninsula, where the Silurian formations rest unconformably on the metamorphosed and folded Ordovician, the basal Silurian also includes conglomerates and thick sandstones.

A striking contrast is seen, however, if we journey 70 miles across the Gulf of St. Lawrence to Anticosti Island, where the Late Ordovician and Early Silurian are both represented by flat-lying formations of calcareous shale or limestone. There is no evidence here of the Taconian orogeny, in either the structure or the sediments. Moreover, there are younger Ordovician beds on Anticosti (Gamache formation) than any known elsewhere on the continent, showing that the Ordovician seas lingered longest here. The explanation of this striking contrast in the record of Anticosti Island and Gaspé lies in the fact that Gaspé was originally much farther south and its rocks have been overthrust many miles to the north by a later disturbance, bringing rocks from the eastern part of the geosyncline near those originally deposited far from the Taconian Range.

The westward gradation of the Early Silurian deposits from sandstone into shale and finally into limestone is exceptionally well displayed in nearly continuous exposures that follow the base of the

Niagara cuesta from Rochester, New York, through Niagara Falls and across the Ontario Peninsula into the Manitoulin Islands (Fig 114)

**Middle Silurian Limestones and Coral Reefs.** West of the Cincinnati arch even the Early Silurian formations are of limestone Although of considerable areal extent (Fig 110A), they are commonly a few feet or a few tens of feet thick and represent only a small part of this epoch, but it is notable that there were no uplands within adequate reach to supply even muds to this part of the interior sea

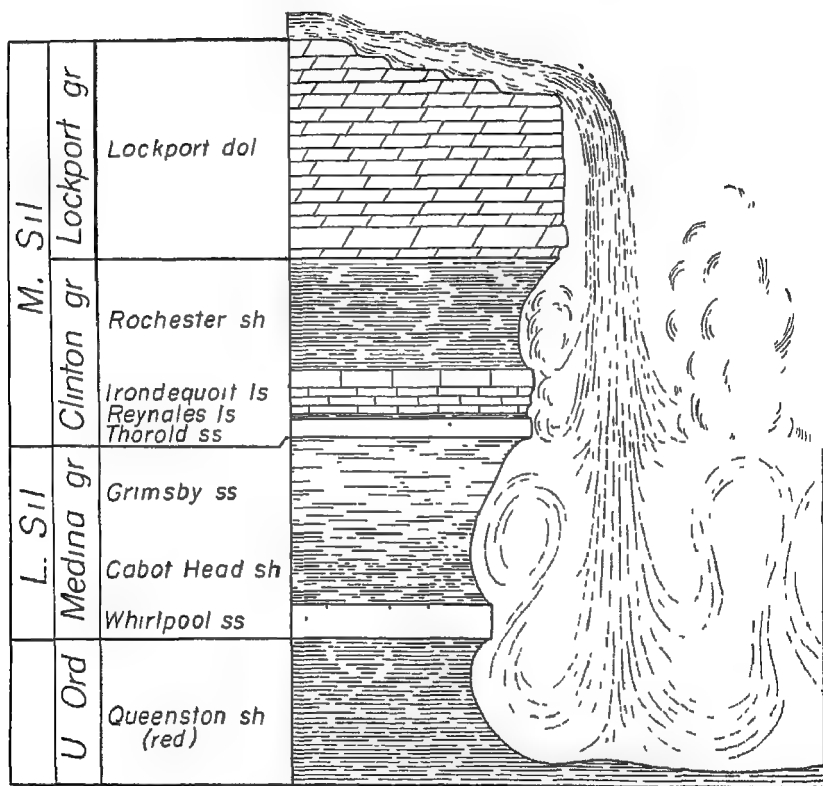



FIG 116 Silurian section at Niagara Falls Height of falls, 158 feet, depth of water, 150–200 feet Section made through Horseshoe Falls Modified from G K Gilbert.

Middle Silurian formations are far more widespread and are considerably thicker, but they, too, are almost entirely made of limestone (locally dolomite in the upper Mississippi Valley) Even where

widely distributed across the Canadian Shield, they are predominantly calcareous

The grand exposures about Niagara Falls (Fig 116) display most of the Middle Silurian in its typical development, resting upon the sandy phase of the Lower Silurian (Fig 115) The lip of the falls is formed by the thick-bedded Lockport dolomite, which also rims the gorge in cliffs more than 100 feet high (Figs 116 and 117) This resistant formation, overlying the weak shales below, holds up the Niagara cuesta across western New York, the peninsula of Ontario, and the Manitoulin Islands north of Lake Huron It extends southward under cover of younger formations, to appear again about the flanks of the Cincinnati arch Large outliers occur farther north in Canada, one of the greatest being along the west shore of Hudson Bay

The rocks exposed above the brink of the falls and along the upper rapids represent the base of the *Guelph dolomite* This formation is typically developed only in Ontario and Ohio, where it is characterized by a peculiar fauna of gastropods, a large clam (*Megalomus*), and heavy-shelled, hingeless brachiopods (trimerellids) The Guelph

F B TAYLOR, U S GEOLOGICAL SURVEY

*Fig 117 Silurian formations at the lower end of Niagara Gorge above Lewiston The base of the Silurian is near the middle of the lower wooded slope*

G K GILBERT, U S GEOLOGICAL SURVEY

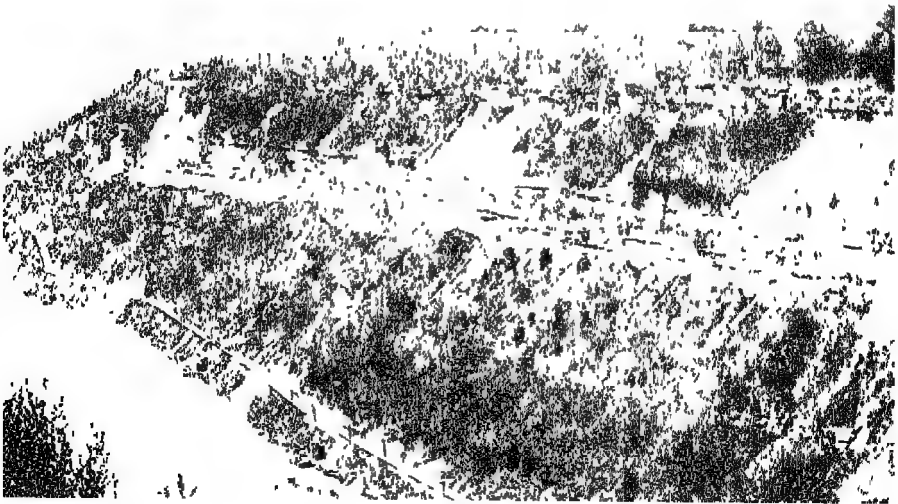



*Fig 118 Small bryozoan reef in the upper limestone (Irondequoit) formation of the Clinton group Niagara Gorge The reef is 15 feet across, and its top projects several feet into the overlying Rochester shale*

fauna appears not to have reached much to the south of central Ohio The Lockport limestone grades westward into dolomite, and to the south and west of Lake Michigan is less easily separated from the Guelph, the two forming a thick group of dolomite beds that extends underground into Kansas and Nebraska, cropping out locally in Iowa

Below the Lockport formation at the falls and in the gorge at Niagara lies the Clinton group, here much thinner than in the Appalachian region and likewise more calcareous

The Silurian of western North America is not well known but is represented by 1000 feet of dolomite in Idaho and Utah and 1500 feet of similar beds in southern Nevada Great thicknesses of dolomite are exposed also in British Columbia, the Mackenzie Valley, the Arctic Archipelago, and southern Alaska

Throughout the extent of the limy Niagaran formations, corals were common and at many places made small reefs Limestones and dolomites with reef structures occur in the Medinan series but are especially common in the Niagaran of Indiana, northern Illinois, southern Wisconsin, Iowa, and Ontario north at least to Lake Huron Some of

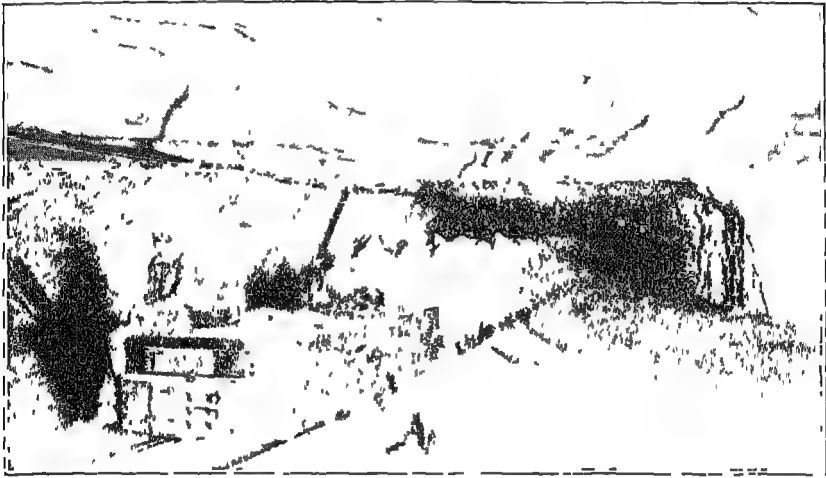
the oldest of these reefs were made by bryozoans (Fig 118), but the majority were formed by various kinds of stony corals (Tabulata, Tetracoralla, and hydrocorallines like the stromatoporoids) These reefs vary in size from several feet to more than a mile across, and in height from a few feet up to 75 feet All are unstratified masses made up of entire or broken skeletons, buried in a matrix of coral sand and mud, the whole more or less altered through diagenesis into either a pure calcium carbonate or a dolomite

*Retsof Mining Company*

Fig 119 A salt mine in the Upper Silurian at Retsof, central New York The tunnel is cut in solid rock salt, and the cars are loaded with salt on their way to the shaft

Although corals were the chief builders, many other groups of animals contributed to these reefs It is more correct, therefore, to speak of them as organic reefs than as coral reefs The name *bioherm* (Gr *bios,* life, + *herma,* reef) has been used for such structures

**Upper Silurian Desert Deposits and Waterlimes** In central New York the salt-bearing shales of the *Salina group,* more than 1000 feet thick, succeed the Niagaran limestone Here the lower half is composed of bright red unfossiliferous shale (Vernon) and the upper half of gray shale (Camillus) with several beds of rock salt The salt (Fig 119) underlies an area measuring 150 miles from east to west and extends southward under southern New York, northern Pennsylvania, and Ohio Several distinct beds occur at intervals in the shale, individual beds of pure salt reaching a thickness as great as 80 feet At Ithaca, New York, where the formation lies between 2000 and 3000

feet underground, there are seven beds of salt with an aggregate thickness of 250 feet, but the greatest accumulation of Silurian salt is deeply buried under the center of the Michigan Basin, where deep wells reveal salt beds aggregating 1600 feet in thickness.[3]

Southeastward toward Appalachia the entire series passes into barren redbeds, but southwestward in central Pennsylvania interbedded limestones (Tonoloway) bear abundant marine fossils at many horizons.

After the salt deposition the marine waters again spread widely over the New York desert, and a series of thin but persistent dolomites and waterlimes was left as the final record of the Silurian period. Waterlime is an impure calcareous sediment with a large admixture of silt, possibly the wind-blown dust from the neighboring arid lands; it was once much used in making cement.

## Climate

**Cosmopolitan Climate of the Middle Silurian.** The coral reefs and coral-bearing strata distributed widely throughout the Middle Silurian limestones show that mild temperatures again extended into the arctic region. The evidence lies not so much in the mere existence of the reefs and corals as in the fact that the species are everywhere identical or much alike, whether in Kentucky, New York, the Hudson Bay region, or within the Arctic Circle, as at Polaris Bay, northern Greenland. The wide extent of the limestones and dolomites confirms the evidence of the corals. Other groups of invertebrates, notably the cephalopods, show an equal disregard for latitude. Certain species found in Iowa are clearly migrants from Europe by way of the polar region. Most remarkable of these is the four-sided coral, *Goniophyllum* (Fig. 120), which, unlike all others, had an operculum, or cover, of four limy plates.

FIG. 120. A distinctive Silurian coral, *Goniophyllum*. Natural size.

**Late Silurian Deserts.** As the continent emerged during Late Silurian time, arid conditions spread over the eastern United States, and a large area including Michigan, Ontario, New York, and Pennsylvania took on the characters of a desert basin. In the midst of this region, a lingering arm of the inland sea shrank to a "dead sea" in

which vast quantities of salt and gypsum were precipitated The red Vernon shales of the Salina group probably represent the muds of a barren coastal plain, where free access of the air to the soil during long periods of drought kept the enclosed iron thoroughly oxidized The gray shales, deposited under hypersaline waters, include salt and gypsum at many horizons over an area of nearly 100,000 square

*Charles Schuchert*

FIG 121 Mud-cracked layers of impure limestone in the Upper Silurian (Salina group) at Roundtop, Maryland

miles Since the deposition of 1 cubic foot of salt (sodium chloride) would require the evaporation of about 80 cubic feet of normal sea-water, it is clear that severely arid conditions must have persisted here for a very long time It is not to be inferred that the water was deep, however, there was probably an intermittent inflow of more sea-water from the outer ocean to balance the evaporation and supply the salt Indeed, the abundant mud cracks in the gray shales (Fig 121) indicate that wide mud flats were repeatedly exposed

The cause for the aridity may have lain in the flatness of the extended land mass, which offered no elevations to chill the westerly winds after they had crossed the interior of the continent

## Economic Products

**Clinton Iron Ore** The red iron ore mined in the Birmingham region of Alabama now supplies about 10 per cent of the iron produced annually in the United States and is the only important competitor of the Pre-Cambrian ores of the Lake Superior region

The Silurian ore is an oolite of the red oxide, hematite, occurring in thin, lenticular beds alternating with the gray shales of the Clinton group The ore locally includes abundant marine fossils and commonly has replaced broken bits of the shells It was originally deposited as a sedimentary accumulation on the Silurian sea floor One or more beds of ore can be found at most of the outcrops of the Clinton shales all the way from New York to Alabama, but the thickness is generally only a few inches to a foot or two, rising locally to 3 or 4 feet

Before the Civil War the Silurian iron was extensively exploited in the region of Clinton, New York, but since the discovery of the vast iron deposits in the Lake Superior region most of the Silurian mines have been driven out of competition In the vicinity of Birmingham, Alabama, however, the Clinton ore beds reach their maximum development, the "Big Seam" having a thickness of 40 feet, of which 15 to 17 feet is rich enough to be workable Here, in immediate proximity to the Big Warrior coal field, the ore is profitably and extensively mined It is estimated that over 600,000,000 tons of this ore are still available underground

**Salt** Salt is another important mineral product of the Silurian rocks During the years 1943–1945 the average annual production of salt from the Silurian rocks of New York State was in excess of 2,900,000 tons and had a value of nearly $10,000,000 This was slightly less than 20 per cent of all the salt mined in the United States The salt is obtained chiefly by forcing water down deep drill holes and pumping up the brine to be evaporated and refined, it is also mined and sold in blocks to be used as salt licks for cattle

## Silurian Life

**The Continued Reign of Marine Invertebrates** Silurian life was a modification, through lineal descent, of that of the Ordovician, with no drastic innovations Marine invertebrates still predominated, almost to the exclusion of other forms of life Some of the invertebrate

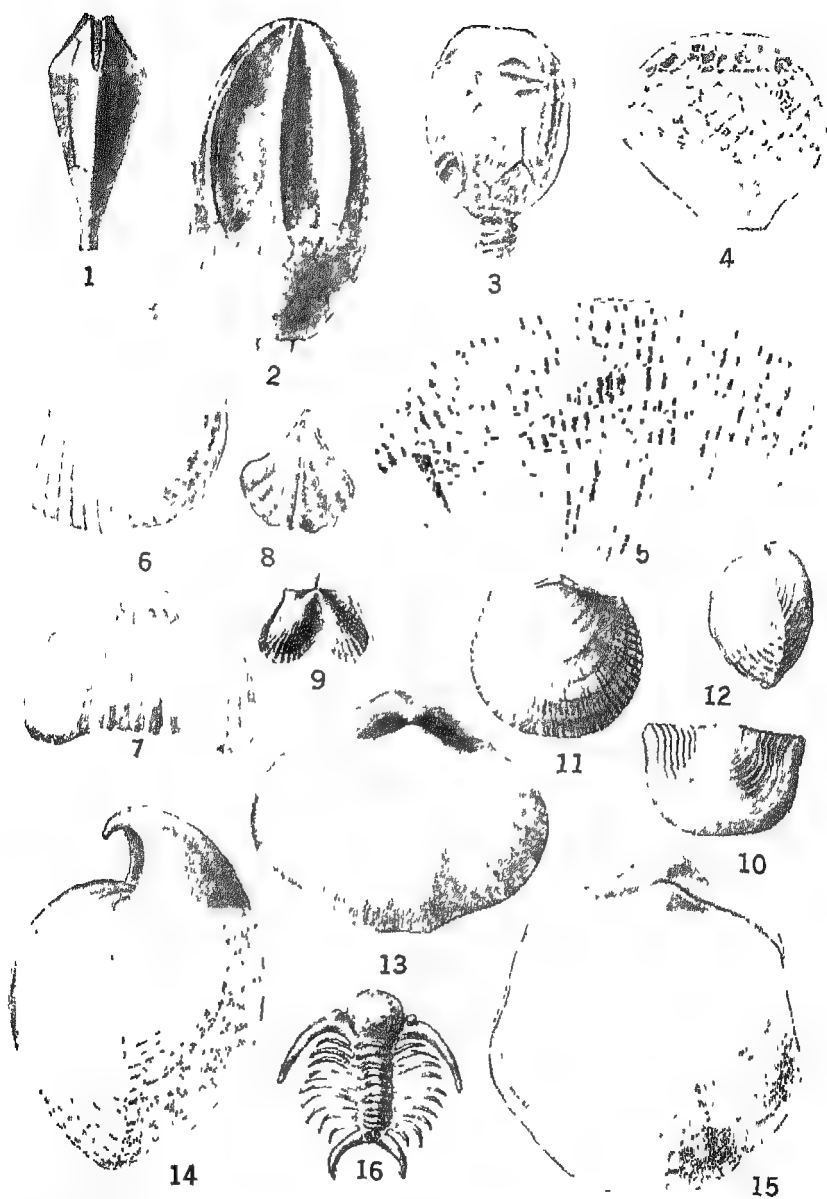



Plate 6 Silurian Blastoid (1), Crinoid (2), Cystoid (3), Corals (4, 5), Brachiopods (6–15), and Trilobite (16).

Fig 1, *Troostocrinus reinwardti*, 2, *Eucalyptocrinus crassus*, 3, *Lepadocrinites manlius*, 4, *Favosites forbesi*, a honeycomb coral, 5, *Halysites catenularius*, a chain coral, 6, 7, *Uncinulus stricklandi*, 8, *Rhynchotreta americana*, 9, *Bilobites bilobus*, 10, *Leptaena rhomboidalis*, 11, 12, *Atrypa reticularis*, 13, *Eospirifer radiatus*, 14, *Conchidium laqueatum*, 15, *Pentamerus oblongus*, 16, *Deiphon forbesi barrandei* All natural size Drawn by R G Creadick

of little importance in the Ordovician, now sprang into prominence

The *graptolites*, for example, had greatly declined and are found at only a few limited horizons in the American Silurian, though in Europe they were still numerically abundant but mostly of one genus, *Monograptus*.

*Corals*, on the contrary, showed an extraordinary expansion into many genera and species including honeycombs (*Favosites*), chain corals (*Halysites*), cup corals, and compound types of tetracorals In the clear Niagaran seas they formed reefs of widespread distribution (Pl 6, figs 4, 5)

*Bryozoa* were still very common and locally made small reefs (Fig 118).

*Brachiopods* showed a marked expansion To the flattish and square-shouldered types were added globular, short-hinged forms with pointed beaks and plicated shells Spire-bearing types also for the first time became common (Pl 6, figs 6–15)

Among the echinoderms, *cystoids* (Pl 6, fig 3) were rather common, *blastoids* (Pl 6, fig 1) just beginning, *starfish* and *echinoids* exceedingly rare *Crinoids* (Pl 6, fig 2), on the contrary, experienced a remarkable evolution and grew in the greatest profusion, their calcareous plates contributing largely to the limy sediments of the clearer seas Growing as they did on graceful, slender stems, these "lilies of the sea" undoubtedly furnished the most colorful spots upon the Earth

The molluscs were generally much less conspicuous than in the preceding period, but in some of the late Niagaran dolomites heavy-shelled *gastropods* are abundant Nautiloids and clams were both present but hardly noteworthy

*Trilobites* had passed their climax but still remained common A number of types showed a tendency toward bizarre development of spines, which may have been a protective measure against the evolving fishes (Pl 6, fig 16)

The *eurypterids*, or "sea scorpions," formed perhaps the most striking and distinctive element in the late Silurian faunas (Figs 122, 123) They are very localized in their occurrence and practically confined to a few limited horizons, but they are common fossils where they do occur They were sparingly represented in the Ordovician but in the Silurian rose to a meteoric climax only to decline abruptly in the next period, after which they were very rare Most of them were small animals from a few inches to a foot or so in length, but a few species attained large dimensions The largest American species (*Pterygotus buffaloensis*) is found in the Bertie waterlime of western New York, where

fragments of exceptionally large individuals have led to an estimate of a body length of 7 feet or a length of 9 feet over all, with pincers extended. This creature ranks as the greatest arthropod of all time.

*Ostracods* continued in great abundance, and some species now attained a relatively large size, the greatest, however, scarcely reaching a length of 1 inch.

**Fishes.** Fishes undoubtedly lived in the streams throughout this period, but their remains are exceedingly rare, consisting essentially of

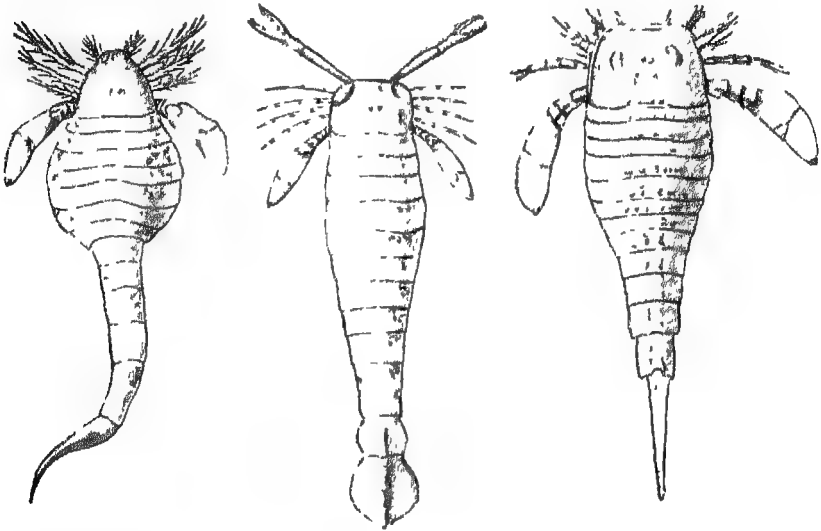



FIG. 122. Three characteristic types of eurypterids. Left, *Eusarcus scorpionis*, ×½; center, *Pterygotus buffaloensis*, ×1/25; right, *Eurypterus remipes*, ×1/3. After Clarke and Ruedemann.

small, bony tubercles and armor plates which studded the skin of certain of the primitive Ostracodermi in lieu of scales. In the highest Silurian beds of Norway,† however, remarkably preserved but very primitive fishes (Fig. 124) have been found in abundance.[3] These have no well-defined jaws, and in this and other primitive characters they appear to be ancestral to the modern hagfish or cyclostome.

**Beginnings of Terrestrial Life.** Fragments of supposed *land plants* have been described from the Silurian rocks of Gotland, England, and Australia. The remains are few, however, and very frag-

† The Silurian age of these beds is not beyond question. Similar beds constituting the typical Downtonian of Scotland are now referred to the basal Devonian.

Fig 123 Reconstruction of eurypterids on a Silurian sea floor After Ruedemann About 1/10 natural size

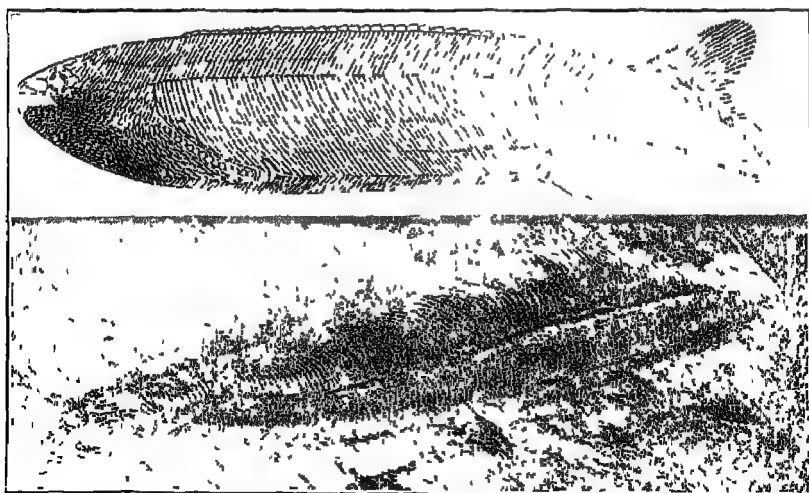



Fig 124 A primitive fish (*Pharyngolepis oblongus*) from the uppermost Silurian (Downtonian beds) of Norway. Above, a reconstruction, below, dorsal view of a specimen in the rock After Kiaer About 2/3 natural size

mentary, consisting of bits of stems some pieces of which bear small, bractlike leaves One of the Australian types bears slender leaves 2 centimeters long and 1 millimeter broad Some of the stems described as land plants may be those of marine algæ

"These Silurian fossils are the oldest examples of what appear to be terrestrial plants They do not tell us very much, but they afford evidence of two Silurian types, probably terrestrial, which agree closely with forms characteristic of the earlier Devonian floras and of a third type that appears to be peculiar to this meagre Pre-Devonian flora " [4] Soft-tissued algæ and fungi may have been abundant in regions of sufficient moisture and suitable climate

Possibly the *first air-breathing animals* were *scorpions* and *millipeds*, both of which have been found rarely in the Upper Silurian rocks These first-known scorpions are small creatures, not over 2½ inches long, and their resemblance to modern scorpions is striking Nevertheless they may still have been aquatic animals They are almost certainly descendants of the eurypterids, which were aquatic, and none of the fossil specimens has revealed the respiratory structures that would prove whether they breathed air or water

The millipeds have been found only in Wales, where they are associated with eurypterids

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[1] *Paleozoic Cordilleran Geosyncline and Related Orogeny*, by A J Eardley Journal of Geology, Vol 55, 1947, pp 309–342

[2] *Geology of the Mackinac Straits Region*, by K K Landes, G M Ehlers, and G M Stanley Michigan Geological Survey, Publication 44, Geol Ser 37, 1945, p 192

[3] *The Downtonian Fauna of Norway, I, Anaspida*, by J Kiaer Vidensk-Skrifter, I Mat-Naturw Klasse, 1924, No 6

[4] *Plant Life through the Ages*, by A C Seward The Macmillan Co, New York, 1931, p 110

## Collateral Reading

*Niagara Falls Folio*, by E M Kindle and F B Taylor U S Geological Survey, Geologic Folio 190, 1913

Treats of the classic section of Silurian formations exposed in the Niagara Falls region

*The Founders of Geology*, by Sir Archibald Geikie Macmillan and Co, London, 1905, pp 412–434

An interesting account of the founding of the Silurian, Cambrian, and Devonian systems

## Chapter 10

# THE DEVONIAN PERIOD

**Discovery of the Devonian System.** In Great Britain, where historical geology had many of its first devotees and the Early Paleozoic systems were named, the Coal Measures are underlain by a great succession of sandstones and shales known to the pioneer geologists as the "Old Red Sandstone." Until Murchison and Sedgwick had defined the Silurian and Cambrian systems, it formed the base of the determined geologic column, and thereafter it was given a place between the Silurian and the Carboniferous.

In 1836 Murchison and Sedgwick began to work in Devonshire and Cornwall, the southwestern provinces of England, which had long been known to be largely covered by a series of gray rocks considered to be Carboniferous because of the presence of fossil plants. They found that only the upper part of these rocks is plant-bearing, the lower part they referred to the Cambrian solely because it was badly deformed and in that respect resembled the rocks of northwest Wales. However, when fossil corals found by local collectors were submitted to the paleontologist Lonsdale, he found them intermediate between corals of the Silurian and those of the Carboniferous, and suggested that these beds might belong to the "Old Red." Murchison and Sedgwick were hard to convince, but after 2 years they accepted Lonsdale's view and proposed the name Devonian for a new system between the Silurian and the Carboniferous. In it they embraced these marine deposits of Devonshire, the Old Red sandstone, and correlative formations elsewhere.

It was eventually found that in Devonshire the system is 10,000 to 12,000 feet thick and consists of graywacke, slates, and limestone, associated with lavas and tuff. The region was an unfortunate one on which to base a system, for the beds are so disturbed by folding, faulting, and intrusions that the detailed succession is still not wholly known. Equivalent but less-disturbed beds had already been described in the Rhine Valley in Germany, and these became the actual standard or type section of the system in Europe. A still finer section in New York State is the standard of reference for America.

## Physical History of North America

**The Devonian Cycle of Submergence** Although the close of the Silurian left Europe rugged and mountainous, North America remained low and flat The Devonian submergence began in the Appalachian trough, which was soon transformed into a narrow strait reaching from Newfoundland to Mississippi and at times separating Appalachia completely from the mainland (Fig 125A) No marine deposits of Early Devonian time are known in the Cordilleran trough, but a fresh-water formation bearing fossil fish and land plants is present at Beartooth Butte in Wyoming During this epoch, probably less than 5 per cent of the present continent was submerged

The beginning of Middle Devonian time was marked by submergence that spread the Appalachian seaway westward to the Mississippi Valley, and soon brought another vast arctic flood creeping southward across western Canada by way of the Mackenzie Valley region in a seaway nearly 1000 miles wide This joined the embayment that then occupied the Cordilleran trough in Utah and Nevada From this time until late in the period the two great geosynclines were more or less persistently submerged and received a great thickness of sediments, but the Central States were barely awash, or slightly emergent, during much of the time The middle and lower maps of Fig 125 represent maximum submergences, but should be considered only temporary stages in an ever-changing scene Possibly 40 per cent of the present continent was submerged at one time or another during both the Middle and Late Devonian epochs, but toward the close of the period emergence was gradual and finally complete

**The Acadian Disturbance.** About the middle of the period, uplift was renewed in Appalachia, and the geosyncline was more rapidly depressed These movements continued with increasing intensity until the close of the period and culminated in the formation of a bold mountain chain that followed the axis of old Appalachia down through the Maritime Provinces of Canada and the New England states and thence southward to about the latitude of Cape Hatteras (Fig 125C) This orogeny was first recognized in the Maritime Provinces—the Land of Acadia—and for this reason it has been named the *Acadian disturbance*

The Acadian Mountains were a second generation of Appalachians, much like the Taconian Range of the Late Ordovician and involving

*Fig 125A (left) Early Devonian (Helderbergian) paleogeography Land areas lightly shaded, shallow seas deeply shaded, deep sea horizontally lined, present outcrops solid black*

*Fig 125B (right) Middle Devonian paleogeography Lined shading in Appalachian region marks the subaerial part of the Catskill delta, other symbols as above This map shows the maximum spread of the early Hamilton seaways The western sea is based on the Stringocephalus fauna*

*Fig 125C (left) Late Devonian paleogeography Symbols as above This represents the maximum submergence of the epoch, during the Chemung age Note the rising Acadian range bordered by the growing Catskill delta*

nearly the same region. In Acadia, as in New England, the Devonian and older sedimentary formations of the geosyncline were strongly folded and much disturbed by igneous intrusion. The effect was both profound and permanent, uplifting and folding all the rocks in this part of the Appalachian trough and destroying its geosynclinal nature so that the seas never again traversed it.

From New England south, the disturbance was east of the present fold belt, in the area of the Piedmont and the Coastal Plain and probably that of the continental shelf. Although the sedimentary rocks have since been destroyed here, and details of the Acadian orogeny can not be restored, the Devonian formations still preserved in the geosyncline indicate the presence of marked highlands at least as far south as Cape Hatteras.

The volume of the sediments derived from the erosion of Appalachia and preserved in the geosyncline gives some measure of the uplift. The detrital Devonian formations from New York to Virginia, inclusive, have been estimated to measure some 63,000 cubic miles. This is approximately the volume of the modern Sierra Nevada, which exceed 75 miles in width, are 400 miles in length, and rise to nearly 3 miles above sealevel along their crest. Since the deposits laid down in the geosyncline were all derived from the western slope of the Acadian mountains, it is clear that Appalachia was much more than 100 miles wide or was very lofty or was continuously uplifted during erosion.

The above estimate does not include the deposits in Acadia or those originally laid down along the mountain front between Acadia and New York and subsequently eroded away.

While the Catskill delta (see p. 206) was forming in New York, a similar great delta was building in Gaspé, and its nonmarine beds near Escuminac, at the head of Chaleur Bay, have yielded land plants and many fishes, including the probable forerunner of land vertebrates (Figs. 138, 139).

**Igneous Activity.** Much igneous activity accompanied the Acadian disturbance. Great thicknesses of bedded lavas and tuffs in southern Quebec, Gaspé, New Brunswick, and Maine record volcanoes that were active during Devonian time. In most of New England and parts of New Brunswick such extrusives have been largely eroded away, exposing the related deep-seated plutonic rocks.

The granite core of the White Mountains is an example. Here the intrusions began during the middle of the period and were renewed on a larger scale as the Acadian disturbance came to its climax.[1]

Other Devonian batholiths are the granites at St George and in the Little Megantic Mountains of New Brunswick,[2] the granites that make up most of Nova Scotia, and those that form the cores of such monadnocks as Mt Katahdin in Maine The great pegmatites of Connecticut are also largely of Devonian age, according to the lead-uranium ratios of their radioactive minerals

**Growth of the Catskill Delta.** As the Acadian mountains rose, erosion was greatly stimulated, and the streams flowing westward into the geosyncline built out a vast compound delta in New York and Pennsylvania The exposed surface of the delta was small in Middle

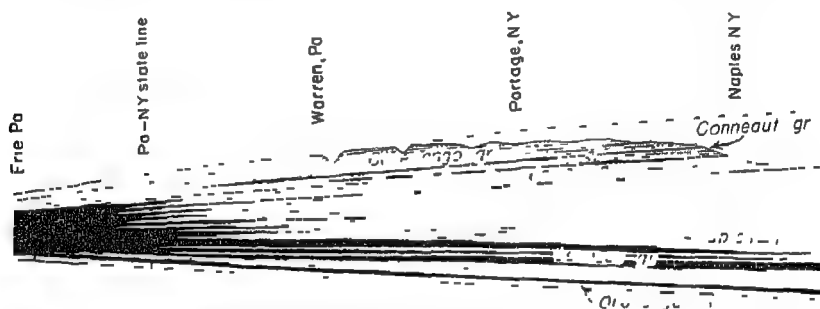



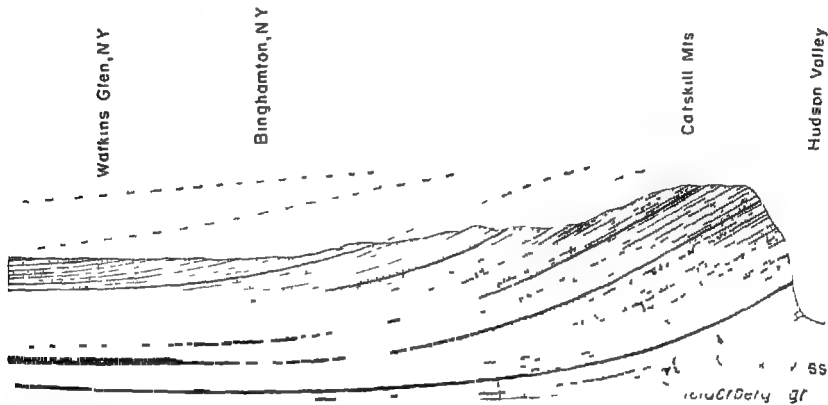
Fig 126 Cross-section of the Catskill delta, from Erie, Pennsylvania, to the Catskill lines indicate the inferred original extent of the beds which have since been partially careous shales in close parallel lines This section is fully exposed along the northern edge

Devonian time but increased steadily during the later part of the period until it became a great alluvial plain more than 100 miles wide, sloping down from the foothills of Appalachia to the inland sea As the region slowly subsided, layer after layer of detrital sediment was spread over it, building up the thick deposit of sandstones, conglomerates, and shales from which the modern Catskill Mountains have been carved The Catskill delta was named for these exposures The terrestrial part of the delta is distinctly shaded in Fig 125*B* A cross-section is shown in Fig 126

## Stratigraphy of the American Devonian[3]

**Appalachian Province.** The Devonian system is exceptionally developed in Pennsylvania and southern New York, where, fortunately, the natural exposures permit its study in three dimensions Magnificent exposures in the fold belt follow the axis of the old Appalachian trough, where Devonian beds are 12,000 to 15,000 feet thick,

and the northern edge of the Allegheny Plateau in southern New York presents a cross-section nearly at right angles to the trough This area is probably unsurpassed as a clear display of the facies changes that are produced in geosynclinal deposits by the growth of mountains in the bordering land The relations are shown in Fig 126

The Lower Devonian formations are relatively thin and are limited to the axis of the geosyncline Two stages are recognized, the *Helder-*

Mountains Section about 250 miles long, vertical scale greatly exaggerated The broken eroded away Redbeds are shaded, black shales are shown in solid black, and gray cal- of the Allegheny Plateau Data from Chadwick and Cooper

*bergian* and the *Deerparkian,* each with several formations The Helderberg stage includes only limestones and calcareous shales, and this shows clearly that near-by Appalachia was then so low that it supplied only fine mud and even that in small volume

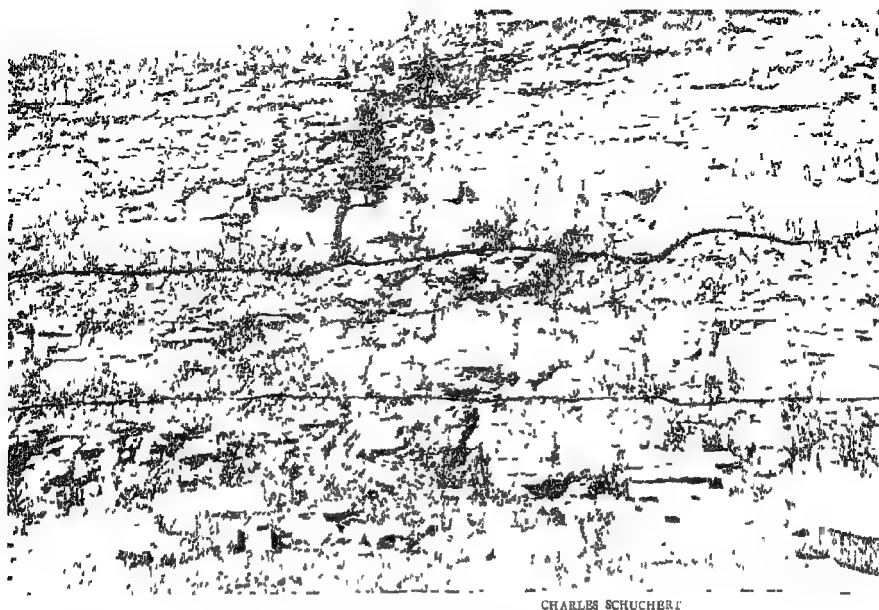
The Deerpark stage is represented here chiefly by the *Oriskany sandstone,* a remarkable formation of nearly pure quartz sand with a calcareous matrix Its distribution is peculiar, being limited to the eastern part of the geosyncline in the Appalachian region, and then reappearing along the Mohawk Valley and extending westward to Mackinac Straits in Michigan The sand was almost certainly derived from two sources, that in the geosyncline from Appalachia and that to the west of the Catskills from the Adirondacks and the Canadian Shield In spite of this extensive distribution, it is commonly only a few feet thick, rising locally to a maximum of 200 or 300 feet in eastern Pennsylvania For several reasons this rather coarse sandstone can not be attributed to uplift of any consequence In the first place, it is thin and is succeeded immediately by a more widespread

CHARLES SCHUCHERT

*Fig 127 Middle Devonian (Onondaga) limestone resting disconformably on Upper Silurian (Cobleskill) limestone in the Bennett quarries at North Buffalo, New York The Bertie waterlime is the source of many of the Silurian eurypterids*

and generally rather pure limestone, and, in the second place, the weathering of crystalline rocks produces vastly more mud than sand, yet this formation has practically no known shaly equivalent It probably represents a sandy mantle that had formed over the crystalline lowlands of old Appalachia and the Adirondacks during late Silurian and early Devonian time, and was now shifted into the sea because of some climatic change that gave the streams more carrying power It certainly does not imply the degradation of highlands

In the fold belt of the modern Appalachians, the Oriskany formation is the chief source of pure quartz for the manufacture of glass

The Middle Devonian begins with the *Onondaga limestone* that extends as an unbroken sheet from the Hudson Valley to central Ohio (Fig 127) Across New York it is commonly about 100 feet thick, but it thins to the southwest It locally grades into shale in Pennsylvania, Maryland, and Virginia, but elsewhere is generally a crystalline limestone Corals are abundant, and reefs are widely distributed and, in places, are of large size One of the most famous of these reefs is crossed by the Ohio River at Louisville, Kentucky, where it forms the "Falls of the Ohio" Obviously, Appalachia was

still low, so that detrital sediment was limited to a narrow belt near shore while the Onondaga limestone was forming

The *Hamilton group,* which succeeds the Onondagan, is a great wedge of detrital material some 2500 feet thick in eastern New York and about 2000 feet thick in central Pennsylvania, thinning progressively toward the west[1] This profound change from the calcareous deposits of Onondagan time was due, of course, to the beginning of the Acadian disturbance Uplift in Appalachia had suddenly begun the rejuvenation of the streams and started them carrying mud and sand This material was sorted and size-graded by the waves and currents that spread it across the shallow sea floor, and the sand and gravel were deposited in the east, while only fine mud reached beyond the geosyncline into Ohio.

Along the face of the Catskills (and down the strike in Pennsylvania) the lower part of the Hamilton group consists of dark-gray silty shale bearing marine fossils This is succeeded by siltstone and gray sandstone, also carrying marine fossils, and these, in turn, by a redbed complex in which red shales alternate with gray sandstone and conglomerate In this upper part, no marine fossils have been found, but land plants are preserved, the imprints of roots are common, and stumps of trees, river clams, and fresh-water fishes occur locally In gray sandstones quarried for the dam of the Gilboa Reservoir, stumps occur in abundance at three distinct levels (Fig 143) Fossils occur mainly in the gray sandstones, while mud cracks are widespread in the red shales

It is quite evident that conditions had changed greatly in this locality during deposition of the Hamilton beds At first this was a muddy sea floor, then a shallow sandy sea floor, finally a lowland across which streams threaded their way through primeval forests These streams were choked with sand and gravel, now preserved as the gray cross-bedded sandstone and conglomerate During floods, red mud from the warm humid slopes of Appalachia was spread widely over the interstream areas Rainfall was seasonal, so that such deposits of fresh mud were dried and cracked into sun-baked polygons before the next flood season Since conglomerates increase in coarseness toward the top of the group, it is evident that Appalachia was rising during Hamilton time

As these redbeds are traced westward along the strike (Fig 126), they are found to grade laterally into gray sandstones bearing marine fossils, and, miles farther west, the sandstones grade into siltstones

and finally into soft calcareous shales, rich in fossils of many kinds. Still farther west the shales become black. The shoreline of any particular time obviously lay where the plant-bearing redbeds are replaced by gray marine sandstone, and the redbeds here record the exposed surface of a great delta.

The Upper Devonian formations generally resemble the Hamilton group. Although divided into six stages, each of these grades laterally from redbeds in the east to black shale in the west.[5] The redbed facies is limited to the eastern margin of the Hamilton group, but in successively higher zones in the Upper Devonian it spreads farther west; obviously the exposed (subaerial) part of the delta was growing, and the shoreline was being crowded back. Late in the period the shore was far out in western New York and in northwestern Pennsylvania. This complex of marine and nonmarine strata was not the work of one great river but a compound delta formed by many streams flow-

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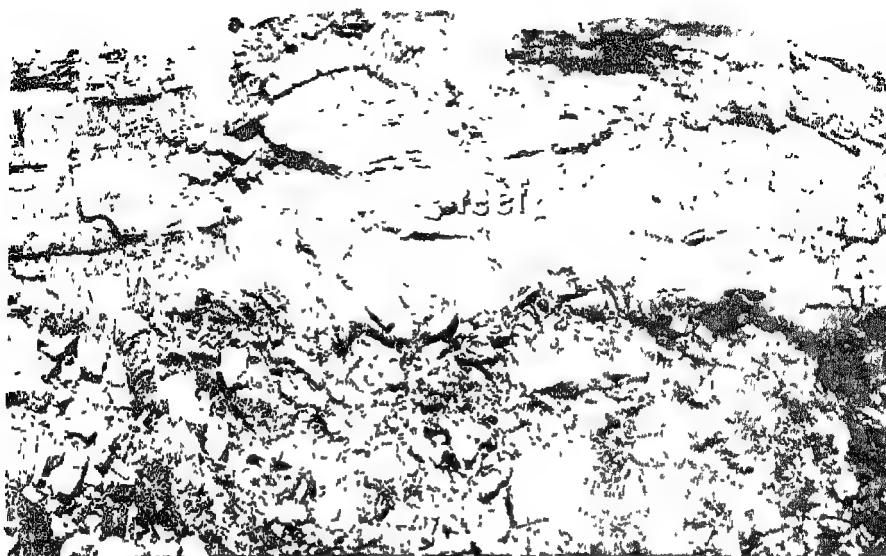
*Fig. 128. Upper Devonian shales and flaggy sandstones of the Naples stage in the gorge of Genesee River near Mount Morris, New York.*

PRESTON E. CLOUD

*Fig. 129. A small coral reef (lighter and nonbedded) in the Alpena limestone at Alpena, Michigan. Larger reefs in the same formation exceed 50 feet in thickness.*

ing northwestward out of Appalachia. The subaerial part formed a wide coastal lowland some 200 miles across, and the subaqueous portion extended clear across the geosyncline. The evenly bedded siltstones and fine sandstones laid down far from shore are well exposed in the gorge of the Genesee River south of Rochester (Fig. 128).

The thickest part of the delta was in Pennsylvania, not far from Harrisburg, where the valley of the Susquehanna exposes about 13,000 feet of Middle and Upper Devonian strata, of which the upper 5000 feet are red. From central Pennsylvania the system thins to the south and west.

West of the geosyncline, in Ohio, Indiana, and Kentucky, the Devonian is thin, and only parts of the period are represented; the Middle Devonian is chiefly limestone, but the Upper is generally black shale.

**Michigan Basin.** Michigan was the site of a basin-like depression separated from the geosyncline by a northward extension of the Cincinnati arch, which was emergent from time to time or at least served as a threshold to prevent the spread of detrital sediments from Appalachia. Here the Middle Devonian is exceptionally well developed, mostly in a limestone facies. Coral reefs are strikingly displayed

in some of these beds (Fig 129) Because of the difference in facies and the partial isolation, the faunas of New York and Michigan are largely different, but a few key horizons can be identified in both and permit the correlation shown in Fig 130

**Cordilleran Province** The Devonian formations of the West are largely calcareous and generally much thinner than those of the East They are also less well known In the deeper part of the Cordilleran geosyncline in eastern Nevada (Eureka district) there is a thickness

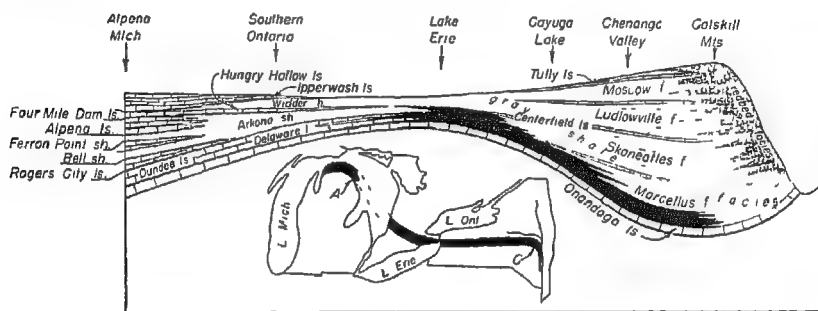



FIG 130 Stratigraphic diagram of the Middle Devonian formations from the Catskill Mountains in New York to the Michigan Basin The inset map shows the outcrop belt which the section follows

Black shale is shown as solid black, gray marine shales are unshaded, the sandy marine facies is stippled, and the redbed facies is more darkly shaded Adapted from G A Cooper *et al* [3]

of 4000 to 6000 feet of limestones and calcareous shales that apparently represent nearly all of Middle and Late Devonian time Elsewhere, in general, only parts of the Middle and Late Devonian are represented, and, except in the Canadian Rockies (Fig 131) and in the lower Mackenzie Valley, the formations are but a few tens to a few hundreds of feet thick Nevertheless certain horizons are represented by very distinctive and widely distributed faunas

Perhaps the most interesting of these is the *Stringocephalus fauna* of Middle Devonian time, marked by the presence of the large and striking brachiopod from which it is named (Fig 132) The original home of this brachiopod is Eurasia It was first discovered in America in the limestones that form the "ramparts" of the Mackenzie River east of Alaska and has since been found in Manitoba, Utah, and Nevada

Another widespread horizon is the *Theodosia hungerfordi zone* in the Late Devonian, which is best known in Iowa but is also widely

spread in the Cordilleran region from Arizona north into Canada and west to the Pacific coast (California).

In the lower part of the Mackenzie Valley the Middle and Upper Devonian formations thicken greatly to the north and pass largely into detrital sediments, indicating local highlands in the far north. In Ellesmere Land, west of northern Greenland, there is also a very thick Devonian section of coarse detritus.

Special interest attaches to the nonmarine strata of East Greenland, which contain a marvelous record of the earliest known land vertebrates along with abundant fishes and land plants.[6] These deposits include red and gray sandstones and shales and at the base have thick, coarse conglomerates. The whole series, which reaches a thickness of at least 3000 and possibly 10,000 feet, implies the rather rapid erosion of near-by highlands that lay to the east of the present coast of Greenland.

CHARLES D. WALCOTT

*Fig. 131. Mount Devon, about 20 miles north of Lake Louise in the Canadian Rockies of Alberta, exposing about 2000 feet of Devonian limestones.*

## The "Old Red Sandstone" of Europe

The early Paleozoic systems (Cambrian to Silurian) have yielded abundant remains of marine life, but not until the Devonian do we get the first clear glimpse of the creatures of the land and the streams There is special fascination, therefore, in the nonmarine Devonian rocks which hold the record of the primeval spread of the forests and the coming of air-breathing land vertebrates The American formations of the Catskill delta have been noted, in the British Isles similar deposits, long known as the "Old Red Sandstone," are vastly thicker and more fossiliferous They lie in a series of five structural basins (Fig 133) that were formed between the ranges of the old Caledonian mountains During Devonian time these basins received the sediments from the rugged mountains just as the California Trough is now being aggraded by the streams from the Sierra Nevada The several narrow basins subsided as they were filled, so that vast thicknesses (up to 37,000 feet) of sands and muds accumulated without allowing the surface of the basins to sink below sealevel

Fig 132 *Stringocephalus*, a large brachiopod characterizing a widespread Devonian horizon in western America and in Eurasia Natural size

The conditions of deposition and the nature of the climate may be inferred from the study of these rocks and their fossils The sediments were commonly poorly sorted and they vary greatly from place to place, these features suggesting the work of streams rather than the sea Conglomerates locally of great thickness and in places including coarse blocks several feet in diameter represent fans built where torrential streams debouched into the basins The purer sandstones are commonly cross-bedded, like the channel sands of streams The siltstones and shales are marked with mud cracks at many horizons, and

in places bear the imprints of Devonian raindrops Obviously these beds are the deposits of floodplains where the mud spread during the wet season lay exposed during the dry months that followed

Although red is the dominant color, there are also thick members of greenish-gray sandstone and siltstone and gray shales The red sediments are completely oxidized, hence they must have come to rest where the drainage permitted good aeration of the soil during the dry seasons The gray beds, on the contrary, were formed where the ground water stood near the surface, or at times when rainfall was distributed throughout the year so as to prevent deep drying and oxidation The widely distributed mud cracks bear witness to seasons of drought, but there are no bedded salt or gypsum deposits in the series, and dune sands are lacking or unimportant Moreover, the abundant fossils show that this was not a desert Instead, it must have been a region of semiarid climate, one in which the rainfall was largely seasonal, so that periods of plentiful moisture alternated with seasons of drought This would cause the frequent wetting and drying of the soil so conducive to the formation of red sediments and would account for the mud cracks on the wide floodplains

Fig 133 Map showing the distribution of the Devonian formations (*black*) in the British Isles The stippled area represents the probable extent of marine and brackish water in Devonian time The other areas, outlined by dotted lines, were intermont basins After Barrell

The dominant animals of the Old Red are fresh-water fishes, of which there are many kinds Eurypterids also are common in the lowest beds Although the earlier eurypterids are generally associated with marine fossils, those of the Devonian and later times are always found with fresh-water fossils and land plants, indicating that by Devonian time they had invaded the rivers, either to spawn or to make their permanent abode Plant fossils are locally abundant

## Devonian Disturbances in Other Countries

During early Devonian time the northern part of the British Isles was the theatre of igneous activity on a large scale. To this time also belong the volcanic rocks in the midland belt of Scotland, as well as part of the granites of this region and of the English lake district. In western Germany the Lower Devonian alone has a thickness of 9750 feet and is evidence that high mountains existed here also.

The most extensive orogeny was in eastern Australia, where the Kanimbla Mountains were formed at the close of the period in a fold belt that stretched the full length of the eastern border of the continent. Much igneous activity had occurred during the period in this region, and the Devonian strata and associated volcanics are said to be over 30,000 feet thick. The uplift and folding at the close of the Devonian were accompanied by the intrusion of granite batholiths.

## Eria, a Great Northern Land Bridge

Throughout Devonian time North America was apparently connected with Europe by a land bridge which later subsided beneath the north Atlantic. This hypothetical land has been called *Eria*. Although the evidence for such a land bridge is circumstantial, it is none the less convincing.

The Acadian folds cross Nova Scotia and Newfoundland and strike along a great circle directly toward Ireland. The present ragged coast lines of Acadia and Newfoundland show that these mountain folds have been broken off and must originally have extended farther east. Likewise, the Caledonian ranges formed in western Europe at the close of the Silurian follow the axis of Scandinavia but curve westward across Scotland and Ireland to strike directly toward the Acadian area. These folds have also been broken off at the west. During Devonian time, moreover, the "Old Red" sediments, which reach such a vast thickness, were coming chiefly from the northwest into Ireland and Scotland from highlands that have since become submerged in the Atlantic. In short, there is clear structural evidence of land extending northeast from the Acadian area and southwest from Britain, and the folds, although of different age on opposite sides of the present ocean, are almost precisely in line. Conclusive evidence that these two lands met is to be found in the land plants and fresh-water ani-

much alike on both sides of the Atlantic that it seems clear they were free to migrate across an easy land bridge. How wide the bridge may have been is now impossible to determine, but it seems probable that the shallow bank between Britain and Greenland, from which the island of Iceland rises, may be a vestige of this old land.

## Climates of Devonian Time

The temperature was doubtless diversified over the Earth and varied locally with changes in relief and in air and ocean currents, but the most striking evidence we have indicates mild climate and a lack of strongly marked climatic belts. For example, coral reefs were more extensively developed in the Mid-Devonian seas than at any other time save the Mid-Silurian. Furthermore, the same genera and species existed in Kentucky, Ohio, New York, and the Hudson Bay region. The same disregard for climatic zones is seen in the fact that several faunas migrated from Eurasia into America by way of the lower Mackenzie basin. This route brought them well within the Arctic Circle and through present polar seas. Examples of this kind are (1) the *Stringocephalus* and (2) the *Hypothyridina faunas* of the Middle Devonian, and (3) the *Theodossia hungerfordi fauna* of the Upper Devonian.

Furthermore, the land plants are much alike in the British Isles, Spitzbergen, East Greenland, and New York. Such distribution of animals and plants would have been impossible if the climatic zones had been strongly marked as they are now.[*]

The redbeds of the Catskill region and East Greenland, like the Old Red of Europe, have been interpreted by some geologists as the deposits of arid basins, but the abundance of fossils, the general lack of wind-blown sands, and other features make this altogether improbable. In the modern world, red soil and red mantle form chiefly where the climate is humid and warm, and where the rainfall is seasonal. The warmth and humidity provide ideal conditions for the thorough oxidation of the mantle, so that the iron is changed to a reddish hydroxide. Strong seasonal rainfall in the basins of deposition allows

[*] The few supposed cases of glacial evidence appear to mark local glaciers, probably of the valley glacier type (Kirk, 1918, in Alaska). The best evidence occurs in South Africa, where the late Lower Devonian (Table Mountain series) has much to indicate the presence of glaciers moving from west to east. On the other hand, Ruedemann has shown that Clarke's evidence of shore ice in New York and Quebec is groundless.

drying and decay of the vegetation, which would otherwise tend to reduce the iron and produce dark colors It also favors the formation and preservation of mud cracks, a very striking feature of the redbeds Although the Devonian redbeds appear generally to have come from warm humid slopes, there is local evidence of considerable aridity in Montana and Alberta where much anhydrite was precipitated during part of Late Devonian time (the Potlatch anhydrite)

## Devonian Life

**Evolution among the Marine Invertebrates.** The Devonian seas swarmed with animals of many kinds (Figs 134, 135) Where the seas were clear, *corals* (Pl 7, figs 1–3) made reefs, and some of the species reached large sizes The greatest of all cup corals, *Siphonophrentis gigantea*, produced individual coralla as much as 3 inches across and 2 feet high Compound species locally formed "heads" as

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*Fig 134 Reconstruction of a bit of a Devonian coral reef, with associated seaweeds, sponges, and other marine animals a, crinoid, b, seaweed, c, corals, d, sponges, e, a snail About 1/10 natural size*

great as 8 feet across Among these reefs the honeycomb corals were especially prominent *Bryozoa* of many kinds, and crinoids as well, also lived on the reefs, and the hydroid "coral," *Stromatopora*, formed encrusting deposits, cementing other shells together

*Brachiopods* (Pl 7, figs 6–16) were now at their climax, and the spirifers were particularly varied No fewer than 700 kinds of Devonian brachiopods are known in North America alone. *Pelecypods* (Pl 8, figs 1–6) found the muddy and sandy bottoms of the Middle and Late Devonian seas to their liking and now became more common and more diversified than ever before Some of these, adapted to burrowing, took on forms much like the modern razor clams, whereas others were attached by elastic threads like modern pearl clams and, like them, became "winged" The *gastropods* (Pl 8, figs 13–15) are not as a rule well preserved or highly diversified *Cephalopods* were varied, although only locally abundant In some of them the margins of the septa were folded or ruffled so that the sutures between septa and shell show strong flexures (Pl 8, figs 9 and 12) These are the primi-

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*Fig 135 Life of a Devonian sea floor Center, a frilled cephalopod (Gyroceras) attacking a trilobite (Homalonotus), left, a large crinoid (Scyphocrinus) and below it a spiny trilobite (Terataspis), right, other trilobites, shells, and seaweeds*

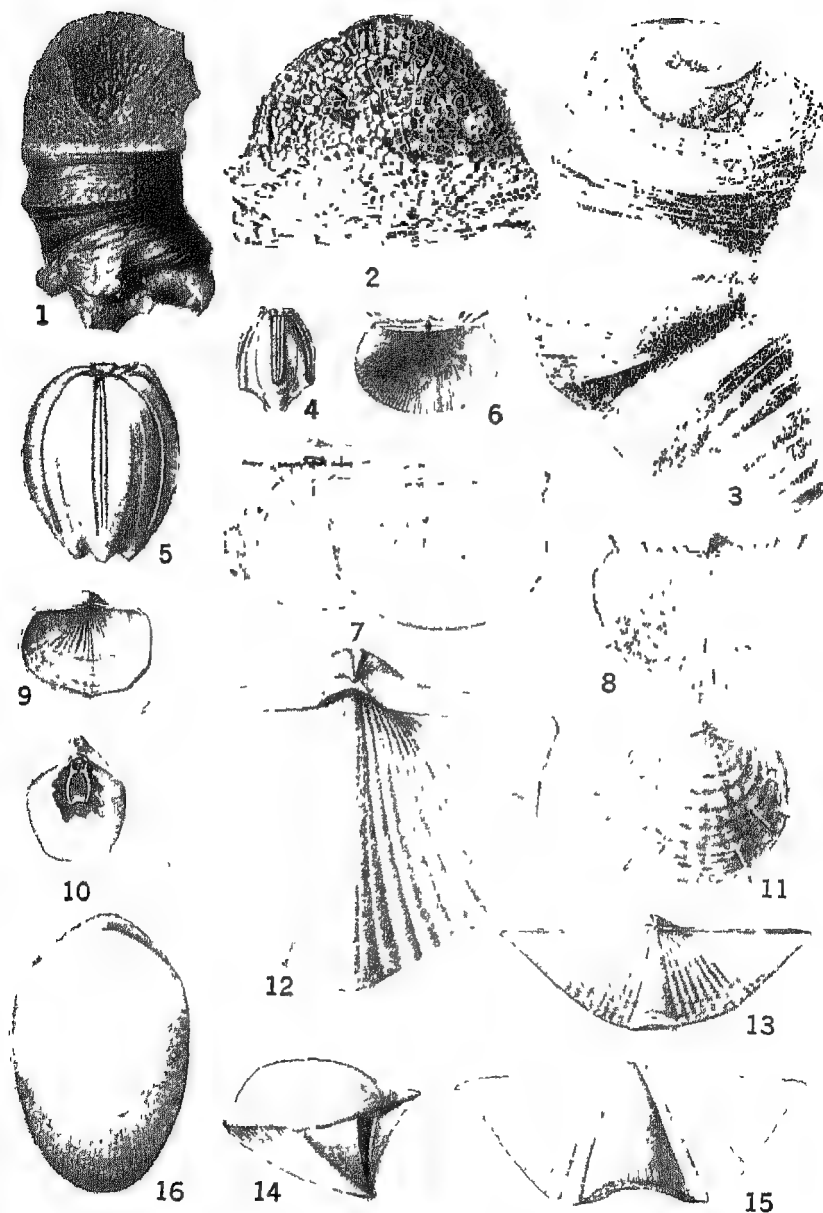



Plate 7 Devonian Corals (1–3), Blastoids (4–5), and Brachiopods (6–16)

Fig 1, *Cystiphyllum vesiculosum*, 2, *Favosites conicus*, 3, *Heliophyllum halli*, 4, *Pentremitidea filosa*, 5, *Nucleocrinus verneuili*, 6, *Chonetes coronatus*, 7, *Strophеodonta demissa* (dorsal view of shell and interior of pedicle valve), 8, *Productella callawayensis*, 9, *Tropidoleptus carinatus*, 10, *Cranæna sullivanti*, 11, *Atrypa rockfordensis*, 12, *Costispirifer arenosus*, 13, *Mucrospirifer mucronatus*, 14, 15, *Platyrachella mesistrialis* (oblique view with ventral beak down, and dorsal view), 16, *Rensselæria elongata* All natural size Drawn by L S Douglass

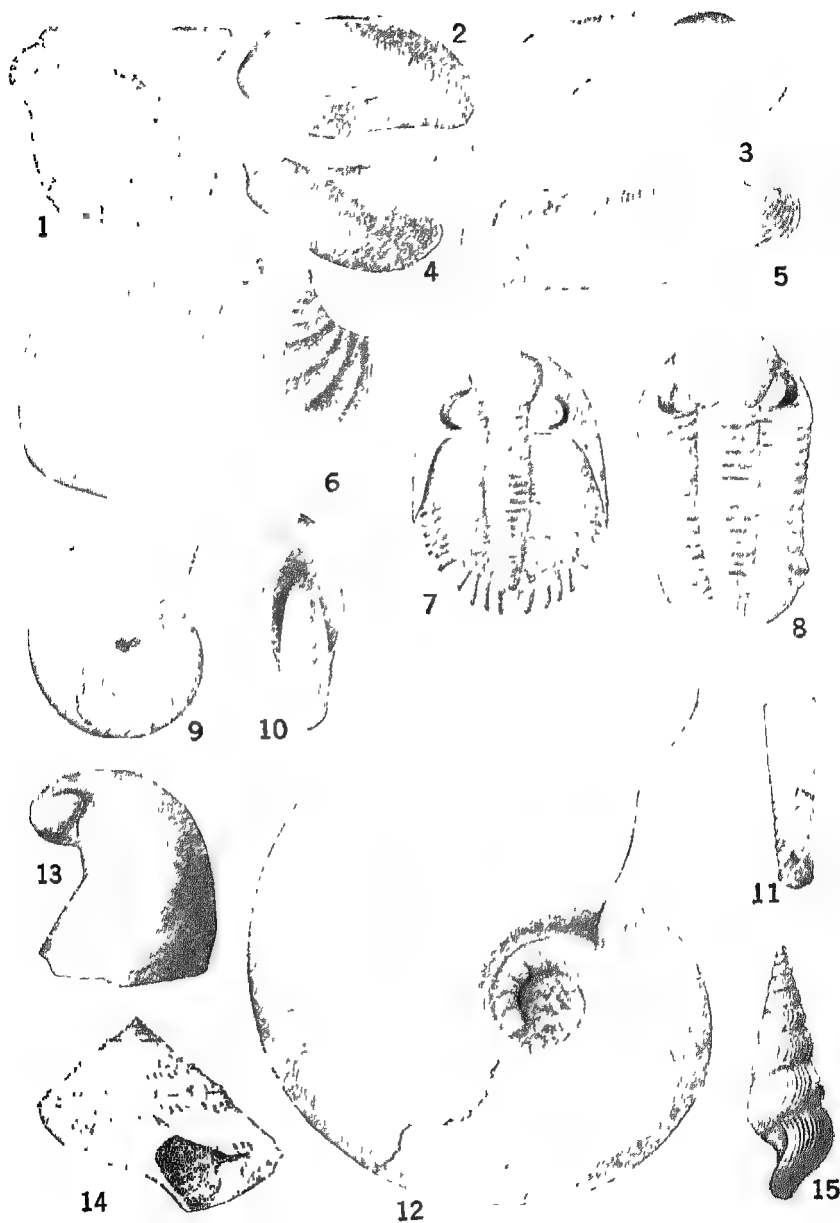



Plate 8 Devonian Pelecypods (1–6), Trilobites (7–8), Cephalopods (9–12), and Gastropods (13–15)

Fig 1, *Cornellites flabellus*, 2, *Nyassa arguta;* 3, *Goniophora hamiltonensis*, 4, *Leptodesma longispinum*, 5, *Orthonota undulata*, 6, *Grammysia bisulcata*, 7, *Greenops boothi*, 8, *Phacops rana*, 9, 10, *Tornoceras uniangulare*, 11, *Bactrites arkonensis* (fragment), 12, *Agoniatites vanuxemi*, 13, *Platyceras reflexum*, 14, *Bembexia sulcomarginata*, 15, *Loxonema hamiltoniae*
All natural size Drawn by L S Douglass

tive forms of the *ammonites,* a tribe of cephalopods that became steadily more important in the Late Paleozoic seas and dominated all other kinds of molluscs during the Mesozoic era. Their appearance at this time is one of the most significant advances in the marine life of the Devonian period.

Although trilobites (Pl. 8, figs. 7, 8) were on the decline and relatively few kinds are found, they were locally abundant, and some among them were of large size, one species of *Dalmanites* reaching a length of 29 inches, probably the record for all time.

Groups that were less common but on the increase were the *blastoids* (Pl. 7, figs. 4, 5), *starfishes,* and *echinoids.* A great slab of Ham-

*American Museum of Natural History*

FIG. 136. Model of the giant arthrodire, *Dinichthys.* Actual length about 20 feet.

ilton sandstone, found at Mount Marion, New York, and now in the State Museum at Albany, originally preserved the casts of more than 400 starfish, some of which died hovering over clams they were in the act of devouring just as the modern starfish eat oysters. *Crinoids* were as common and varied as in the Silurian. Siliceous sponges, somewhat like the modern "Venus' flower basket," were locally abundant, especially in the Late Devonian in central New York.

**Ascendancy of the Fishes.** Although scattered bony plates occur in rocks as old as Middle Ordovician, fish remains are extremely rare until we come to the Devonian, and then they are locally abundant and highly diversified. This must have been a time of rapid evolution for the group, since before the close of the period several of the great orders of fishes were present, and they were widely distributed in the seas and in lakes and streams.

Sharks were common in the seas, but are known chiefly from teeth and fin-spines, since their skeleton is cartilaginous and their scales microscopic. The majority of the sharks were small and of normal form, but one group specialized remarkably and developed into the

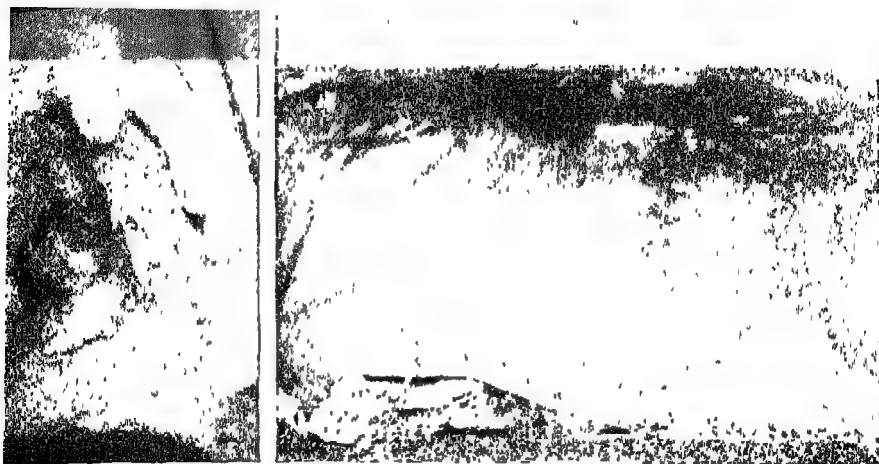



*Fig. 137. The African lungfish, Protopterus. Left, the fish in its "cocoon" as it was shipped from Africa to Chicago in an open tin can. The shipment was in transit for more than 6 months, during which time the fish lived thus encased in dried mud. Right, the same after being placed in an aquarium. From Turtox News, through the courtesy of the General Biological Supply House, Inc.*

largest animals of the time. These are the *Arthrodira*, of which the genus *Dinichthys* (Fig. 136) reached a length of 20 feet. Unlike other fish, the arthrodires bore a heavy armor of bony plates that not only covered the head but also, like a cuirass, reached back over the front part of the body. The plates that covered the jaws were developed into shears that took the place of true teeth. The arthrodires were an aberrant group of sharks that evolved rapidly, achieved great size, became too specialized, and died out early in the next period.

Far greater interest attaches to the *Choanichthyes*, a primitive stock of air-breathing fishes that was dominant in Devonian time but is now nearing extinction. The name refers to a feature not found in any other fishes, namely, a pair of openings in the roof of the mouth which communicate with the external nostrils and permit breathing through the nose, as in land animals (Gr. *choana*, internal nostril, + *ichthyos*, fish). This is the stock from which all the higher vertebrates were to develop.[7]

At least five genera of this group are still extant, but unfortunately they occupy remote parts of the world and are not commonly known. Perhaps the most remarkable is *Protopterus*, the African lungfish (Fig. 137), which lives in the upper reaches of the Nile, where humid winter seasons alternate with dry summers. During the wet season *Protopterus* swims about and breathes by means of gills like any other

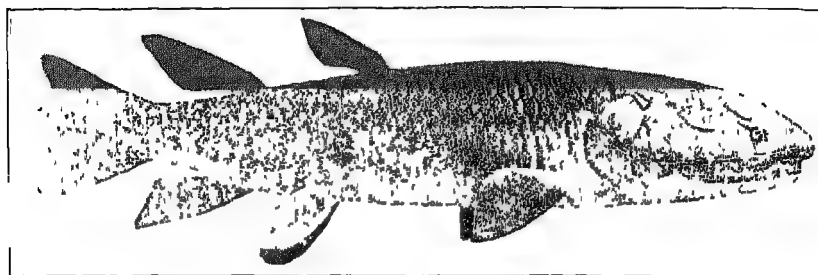
fish, but during the summer, when the swamps go dry, it burrows down into the mud and makes a juglike chamber, where it goes into a rest-

*Yale Peabody Museum*

FIG 138 The Devonian crossopterygian, *Eusthenopteron foordi*, from the Upper Devonian beds near Escuminac, Quebec Actual length of the fish about 2 feet A model by George G Simpson

ing stage like hibernation. Unlike the condition in most fishes, its swim-bladder is connected with the throat, so that air can be inhaled or exhaled at will, furthermore, this organ is supplied with a plexus

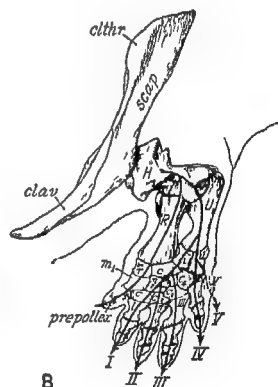
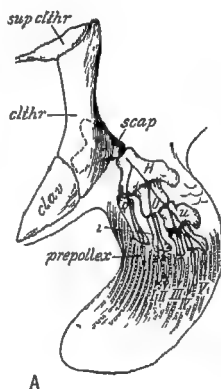



FIG 139 Resemblances between a crossopterygian fin and the limb of a primitive land animal Left, unretouched photograph of the left front fin of *Eusthenopteron foordi*, center, diagram of the skeletal elements of the same fin, right, the corresponding limb of a late Paleozoic amphibian, *Eryops* Photograph from W L Bryant, diagrams after W K Gregory For a restoration of *Eryops*, see Fig 193.

of blood vessels which have the power to absorb oxygen and discharge carbon dioxide In short, the swim-bladder in this fish is a rudimentary lung in both structure and function As the water disappears

during the dry season, *Protopterus* is thus able to breathe air like a land animal, but with the return of the wet season it wriggles out of its mud "cocoon" and swims and breathes again like a normal fish

A different and perhaps more significant habit is shown by another living lungfish, *Neoceratodus*, which is found in the rivers of arid northern Australia During the dry seasons it continues to swim about, merely coming to the surface more often for a breath of air, as the water becomes so stagnant that gill-breathing is inadequate Its rudimentary lung merely supplements the gills at all times, but it permits this fish to live where the water becomes so stagnant and foul that others perish

Fig 140 *Ichthyostegia eigili*, a late Devonian labyrinthodont from Mount Celsius, East Greenland Dorsal and side views after Save-Soderbergh through the courtesy of Lauge Koch Length of skull about 6 inches

In Devonian time the Choanichthyes included two great tribes, the *Dipnoi* and the *Crossopterygii* The living examples described above belong to the Dipnoi, and like all the fossil representatives of that group, they are deficient in having very weak fins, in lacking true teeth, and in other respects which indicate that none of them could be ancestors of the higher animals The Crossopterygii, on the other hand, show a combination of characters that makes them almost a perfect connecting link between fishes and the lower tetrapods, that is, the four-legged, air-breathing vertebrates

The *Crossopterygii* (Gr *crossoi*, a fringe, + *pterygion*, a fin) are so named because their fins have a stout muscular basal lobe beyond which the fin rays extend as a fringe The fleshy basal lobe, lacking in other fish, is the significant thing, for it is the forerunner of the limb of higher animals

Of Devonian Crossopterygii perhaps the best known, and certainly one of the most significant, is *Eusthenopteron* (Fig 138), remains of which are abundant and exceptionally preserved in Upper Devonian beds near Escuminac, Quebec Three features are noteworthy (1)

the stout skeleton in the basal lobe of each fin (Fig 139), (2) the pattern of bony armor plate on the head, and (3) the sharp conical teeth, in which the covering enamel is deeply and intricately infolded

*Yale Peabody Museum*

FIG 141 A labyrinthodont tooth, side view and cross-section (X 5) The creases on the surface are due to infolding of the enamel as revealed in the cross-section Position of the section is indicated by the dashed line across the side of the tooth

**Emergence of the Tetrapods.** It is no accident that the appearance of primitive tetrapods followed closely upon this rapid evolution of air-breathing fishes In 1928 a Danish expedition working in East Greenland, under the leadership of Lauge Koch, came upon well-preserved skulls and incomplete skeletons of the oldest and most primitive of the land vertebrates yet known (Fig 140) They occur in some abundance in nonmarine beds of late Devonian age that closely resemble the Old Red sandstone of England The skulls range in length from 4½ to 7 inches and indicate sprawling animals shaped like a young crocodile and 3 or 4 feet long They represent the *Labyrinthodontia*, a primitive group of amphibians, so named because the enamel on their teeth is complexly infolded, presenting, in cross-section, a labyrinthine pattern (Fig. 141) Nearly all the Paleozoic amphibia were labyrinthodonts (Gr *labyrinthos*, labyrinth, + *odous*, tooth)

It is now quite clear how the tetrapods evolved from the air-breathing fish and why the first ones were *Amphibia* Members of that great class, which includes salamanders, toads, and frogs, are still incompletely adapted for life on land They return to the water to spawn and lay small and simple eggs which, like those of fishes, hatch into tadpoles that breathe by means of gills and are essentially fish-like until partly grown, when legs bud out from their sides, lungs develop from their throat, and the gills are resorbed Then they leave

the water and breathe air. But they still are not quite fully adapted to land life; they must return to the water to spawn, and most of them remain in moist places and spend part of the time in the water. Comparative anatomy and ontogeny both indicate that they evolved from fishes, and the geologic record indicates rather clearly when and under what circumstances the change took place.

The "Old Red" type of Devonian formations accumulated over basin floors where the rainfall was seasonal. Such conditions persisted throughout much of Devonian time in eastern North America and western Europe, and here for millions of years the fish living in the streams and evanescent lakes had to endure annual seasons of drought. Again and again the shrinking waterholes brought death and destruction—but always there were some that did not go dry, and there the survivors were crowded in stagnant water, starving for oxygen. A great premium was thus placed on ability to gulp air and to use the

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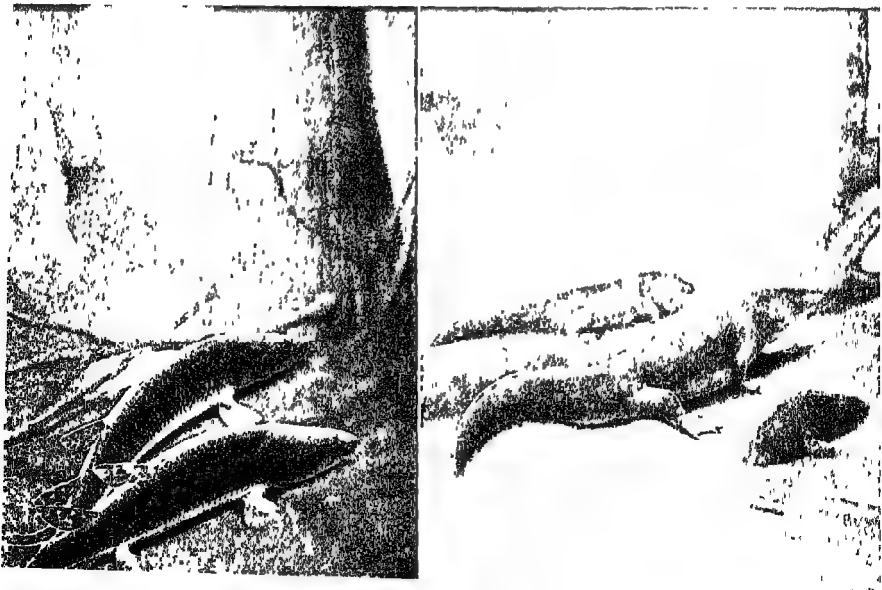
*Fig. 142. Stages in the transition of the lungfishes into labyrinthodonts, as reconstructed by W. K. Gregory. Left, the Devonian crossopterygian, Eusthenopteron, leaving the water to flounder about on its strong muscular fins; right, an early labyrinthodont, Diplovertebron, from the Lower Carboniferous beds of Bohemia.*

oxygen straight. Fishes with swim-bladders that could function as lungs were thus at a great advantage and were stimulated to ever greater activity as the oxygen in the water was depleted. Those with stout fins like *Eusthenopteron* could forsake their pools in the cool of the night and flounder about the banks in short forays for food. Once the lungs had reached a certain efficiency and the fins had been modified into stubby limbs, land vertebrates had arrived! The environment, of course, had not produced these modifications; it had simply selected ruthlessly those random variants that appeared from time to time and were better adapted to survive under such exacting conditions.

The transition from fish to tetrapod, as pictured by W. K. Gregory,[8] is shown in Fig. 142. It is supported by so many detailed technical facts that the Devonian crossopterygians are now accepted by virtually all zoologists as the ancestors of the tetrapods. For example, if we compare *Eusthenopteron* with an early amphibian, we find corres-

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*Fig. 143. Reconstruction of the Middle Devonian forest at Gilboa, New York. Remains of this old forest were discovered during construction work for the Catskill reservoir. The foreground represents actual rock outcrops with three horizons of petrified stumps in place, and the background gives a vista into the forest as it existed in Devonian time. e, the seed-fern, Eospermatopteris; p, a primitive scale tree, Protolepidodendron.*

pondence in the head armor, plate for plate, we find the same elaborately intricate infolding of the enamel of the teeth (Fig 141), and there is a correspondence in other skeletal parts that can not be attributed to coincidence In this connection it is significant that the Devonian labyrinthodonts are more primitive than any others yet known in at least two respects, both of which emphasize their close relationship to the fishes One of these is the submarginal position of the external nasal openings (Fig 140), and the other is the character of the "lateral line" system (a specialized sense organ) that has the form of subsurface canals, as in fishes, whereas in later amphibia it forms only shallow grooves

Fig 144 Primitive Devonian land plants *A*, *Asteroxylon mackiei*, and *B*, *Hornea lignieri*, from the Lower Devonian beds of Rhynie, Scotland About 1/3 natural size After Kidston and Lang

**Land Plants and the Spread of Forests** Evidence of land plants is very scarce before Devonian time but plentiful thereafter, and by Middle Devonian time there was a considerably diversified flora of primitive trees, some of which have left petrified stumps more than 2 feet in diameter Among these were tall, slender *scale trees* (Fig 143), primitive evergreens with large bladelike instead of needlelike leaves, and abundant ferns and *"seed ferns"* These were the forerunners of the Coal Measures floras of Pennsylvanian time and in general were much like the latter

Although soft-tissued plants were probably common long before the Devonian, no fossil wood has been found in pre-Devonian rocks Yet no later age has failed to yield abundant evidence of land plants We can not avoid the inference, therefore, that the Devonian possessed the first forests that ever clothed the lands We need to turn to the treeless barrens of the present world to appreciate what the Early Paleozoic lands looked like and to realize the significance of this great advance in the Devonian

The oldest known deposit of well-preserved land plants is in rocks of the Old Red series near Rhynie, in the Scottish county of Aberdeen

The wonderfully preserved plants found there represent almost the simplest possible type of structure a land plant could have, and suggest the steps whereby an aquatic alga adapted itself for land life. Two of these earliest of land plants are shown in Fig. 144.

Associated with these plants and equally well preserved are the remains of 3 genera and 18 species of spiders, 1 form of mite, and a primitive wingless insect, showing that the air-breathing arachnids and insects had their rise at least as far back as Early Devonian time.

Primitive land plants have now been found in abundance in the Lower Devonian of Belgium[9] and of Wyoming.[10]

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## Collateral Reading


*The Old Red Sandstone*, by Hugh Miller. 427 pages. Revised ed., 1858.

*The Heart of Gaspé*, by John M. Clarke. 292 pages. The Macmillan Co., New York, 1913.

A charming account of this quaint region and its people, as seen by a geologist at his leisure.

*L'Île Percée*, by John M. Clarke. 203 pages. Yale University Press, 1923.

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Chapter 11

# THE MISSISSIPPIAN PERIOD

**The Carboniferous System.** The coal-bearing rocks of Europe and eastern North America were among the first to attract the attention of geologists. As early as 1808 the Belgians referred to them as the "bituminous terrain," and in England they were long known as the "Coal Measures." The name *Carboniferous* was introduced by Conybeare and Phillips in 1822, when they attempted the first general account of the geology of England and Wales. The word "system" had not yet come into vogue, and they proposed the term "Carboniferous order" to embrace the Coal Measures and three underlying groups: (1) the Millstone grit and shale, (2) the Mountain limestone, and (3) the Old Red sandstone. The "Old Red" was transferred to the Devonian system in 1839.

The Coal Measures in time were distinguished as the *Upper Carboniferous,* and the barren groups below as the *Lower* or *Sub-Carboniferous.* The same distinction was useful in America, where the Upper Carboniferous rocks contain practically all the rich Paleozoic coals, and the Lower Carboniferous is barren. In 1891 the U. S. Geological Survey recognized these divisions as formal units and gave each a geographic name, designating the upper the *Pennsylvanian* and the lower the *Mississippian series* of the Carboniferous system. In 1906 Chamberlin and Salisbury pointed out that these units not only differ in lithology over much of the continent but also are separated by a major and very widespread hiatus, and they argued that each should be given the rank of a distinct system. This proposal has steadily gained favor and is now accepted by nearly all American geologists.[1]

The American usage has not been adopted, however, by most European geologists, who still generally recognize the Carboniferous system.*

* The U. S. Geological Survey also officially recognizes the Carboniferous system and treats the Mississippian and Pennsylvanian as subsystems, although many members of the Survey privately advocate recognizing them as systems.

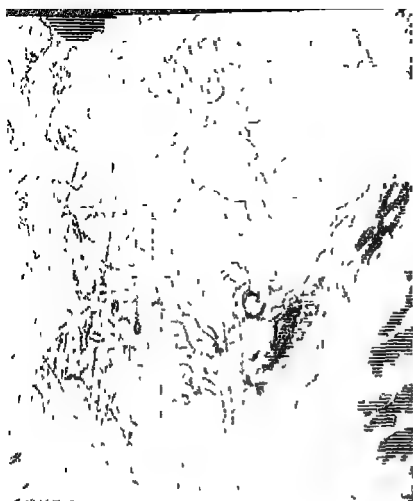



*Fig 145A (left) Early Mississippian (Middle Kinderhookian) paleogeography Land surface lightly shaded, shallow sea deeply shaded, deep sea horizontally lined, present outcrops in black Chiefly nonmarine deposits are marked by black lined overprint*

*Fig 145B (right) Middle Early Mississippian (Osagian) paleogeography Symbols as above This represents the maximum submergence for this period*

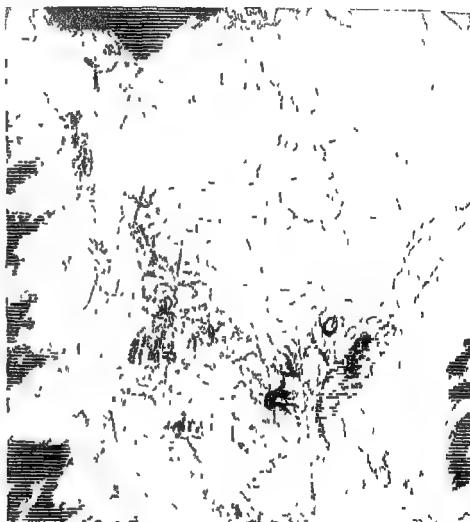



*Fig 145C (left) Middle Late Mississippian (Middle Chesterian) paleogeography Symbols as above*

## Physical History of Mississippian Time

**The Mississippi Valley Seaway** The Acadian disturbance at the close of the Devonian period elevated Appalachia into mountains and transformed the surface of the geosyncline into a broad alluvial plain The central and western part of the continent meanwhile remained low, and the next submergence brought an inland sea over the region of the modern Mississippi Valley For the long and richly fossiliferous record formed here the Mississippian system was named

As suggested in Fig 145, the sea not only entered this region first but occupied it more persistently than any other during this period Nevertheless, the water was generally shallow, and the region was partially or completely emergent at several times

**Restless Appalachia.** Throughout the Mississippian period the Appalachian trough continued to subside, but, inasmuch as it was constantly aggraded by sediments derived from Appalachia, it remained for the most part an alluvial plain barely above sealevel At times the subsidence was more rapid than the filling, and the sea crept eastward across the geosyncline only to be crowded back eventually as the heavily loaded streams from the east gained the ascendancy Thus the shoreline fluctuated back and forth across the geosyncline while thousands of feet of detrital sediments accumulated (Fig 148)

Meanwhile, Appalachia remained a rugged upland in spite of active erosion, and during the latter part of the period was ever more strongly uplifted until the sands derived from it spread as far west as Illinois Obviously this ancient marginal land was rising during Mississippian time Toward the close of the period, it was a highland, at least as far south as Alabama At the same time movement was beginning in Llanoria, a marginal land then occupying the site of Louisiana, eastern Texas, and part of the present Gulf of Mexico It is probable that by this movement Appalachia and Llanoria were united and the old connection to the Atlantic via Alabama and Mississippi was permanently cut off, meanwhile a new passage to the west of Llanoria and across Mexico was opened to remain a dominant seaway until the close of the era

**Beginning of Changes in the West** Early in the Mississippian period the Cordilleran trough was widely flooded, and the pattern of land and sea was similar to that of Devonian time The presence of typical marine faunas as far north as Peace River (lat 58°) in the Mackenzie Valley indicates that the sea for a time connected with the

Arctic. By the middle of the period, however, the sea had vanished from the northern part of the Cordilleran trough, although it persisted in the central and southern parts during much of the period, as proved by sections in southern Alberta and British Columbia, and in Utah and Nevada. Meanwhile the sea had broken across Cascadia to cover northern California, and a new trough, running near the present coastline, brought a seaway southward into central Oregon, bearing a peculiar and distinctive Eurasian fauna not known elsewhere in America. The paleogeography of this western region is still imperfectly known, and the interpretation given in Fig. 145 is tentative.

**Closing Episodes of Uplift and Orogeny.** In North America, Late Mississippian time was marked by more widespread disturbance than any previous part of the Paleozoic era, as mountains were made not only throughout the length of Appalachia but in Llanoria and in parts of Colorado as well. These movements were the forerunners of others that followed intermittently during the rest of the Paleozoic era and culminated in the Appalachian revolution in the Permian.[2]

Over the interior of the continent this late Mississippian unrest was marked by emergence and extensive erosion but without sharp deformation, the intense movement being confined to the marginal lands, Appalachia and Llanoria. As a result, the Mississippian strata, either in the geosyncline or through the central states, generally lie parallel to the overlying Pennsylvanian, and evidence of marginal uplift is seen only in the detrital character of the deposits.

During the long interval of erosion, the early Mississippian limestones of the Ozark region in Missouri and southeastern Kansas were subjected to erosion and developed a karst topography with many sinks and underground caverns. These were in part filled later by the basal Pennsylvanian formations.

*Beginning of the Colorado Mountains.* Although limestone accumulated widely over Colorado during the early part of the period, later uplift in the area of the modern Front Range caused it to be locally removed. The section restored in Fig. 146 gives the evidence for this uplift. In the rim of the Black Hills, which was far from the disturbance, Mississippian limestones are succeeded without discordance by Pennsylvanian limestones. In the Hartville uplift, however, the Mississippian limestone is overlain with spectacular unconformity by red shales and sandstones of early Pennsylvanian age, box canyons as much as 100 feet deep in the light gray limestones being filled with the redbeds.

The abrupt change from limestone to detrital sediment clearly indicates that uplift had taken place and that adjacent lands were being eroded. Indeed, the deep canyons in the Mississippian rocks prove that the Hartville region itself had been temporarily uplifted. Farther west, along the margin of the Front Range, the Pennsylvanian redbeds overlap on Pre-Cambrian granite, but their basal layers include chunks of residual chert, bearing Mississippian fossils. It is therefore evident that the Mississippian limestones were once present here and had been eroded away before Pennsylvanian time. Since the limestones are still present in considerable thickness in the Leadville

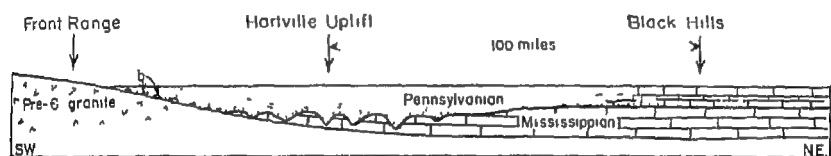



FIG. 146. Idealized section from the Rocky Mountain Front Range near Ingleside, Colorado, to the Black Hills of South Dakota, showing the relations of the Mississippian formations during Pennsylvanian deposition. Fossiliferous boulders of Mississippian rock in the basal Pennsylvanian conglomerate are indicated by the letter *b*. Length of section, about 225 miles. Vertical scale greatly exaggerated.

region farther west, the uplift was obviously between Leadville and the Hartville area, and it probably took the form of a broad arch or dome. This disturbance marks the beginning of the Colorado Mountains, an uplift that persisted into the next period.

*Beginning of the Ouachita Disturbance in Llanoria.*[1] A very thick mass of detrital formations in the Ouachita (*wŏsh'ĭ tô*) Mountains of Arkansas and southeastern Oklahoma also reflects strong uplift in Llanoria near the close of the period. Llanoria was a land mass then occupying the area of the modern coastal belt of Arkansas, Louisiana, and east Texas and probably the northern part of the Gulf of Mexico. It was repeatedly uplifted during the Pennsylvanian period, and in the Permian was thrust northward, crushing the thick Paleozoic deposits of the Ouachita geosyncline and driving them northward in a great overthrust arc to form the Ouachita Mountains. The basal part of this thick detrital mass was formed, of course, during the early stages of the uplift, but unfortunately it is still not certain whether it is late Mississippian or earliest Pennsylvanian (see p. 247).

There was also marked uplift in southern Appalachia near the close of Mississippian time, producing a highland that supplied the 2000 feet of detrital sediments (Parkwood) at the top of the system and the

great volume of early Pennsylvanian sediments that are now represented in Alabama by 9000 feet of strata

**Variscan Mountains of Europe.** During the Late Paleozoic, southern Europe experienced long-continued, extensive, and complicated orogeny. This resulted in a great chain of mountains (Fig 147) that ran southeastward from Ireland across England to southeastern France, then curved northeastward across Switzerland and southern Germany into Bohemia and Austria They have been called the Paleozoic Alps, the Hercynian Alps, or the Variscan Mountains The last name is preferable, since these mountains had no genetic relation to the modern Alps

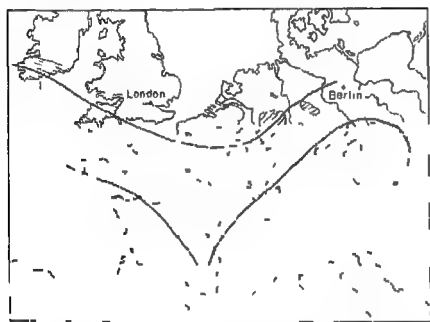



FIG 147 Map showing distribution of the Variscan ranges of late Paleozoic date The "stumps" of these ancient mountains are now exposed in the shaded areas 1, southern Ireland, 2, southwestern England, 3, Armorican Massif, Brittany, 4, central massif of France, 5, Vosges Mountains, 6, Black Forest, 7, Ardennes, 8 Erzgebirge Adapted from E Kayser

The growth of the Variscan Mountains involved folding and faulting as well as much igneous activity This crustal movement embraced not a single disturbance, but three, one at the end of Mississippian time, one during the middle of the Pennsylvanian, and another at the end of the Permian In some regions the chief disturbance came at one time, and in others at another In parts of France and Germany the major folding occurred at the close of Mississippian time There was also much volcanic activity during the Mississippian period in England as well as on the Continent The Kuen-Lun Range north of the Himalayas likewise suffered marked disturbance at the close of this period

## STRATIGRAPHY OF THE MISSISSIPPIAN ROCKS [1]

**Appalachian Province.** The Mississippian rocks formed east of the Cincinnati arch contrast in almost every respect with those farther west While the Appalachian geosyncline was trapping the sands and muds from Appalachia, the low Cincinnati arch served as a threshold to check the westward movement of detrital sediment As a result the Mississippian formations of the Appalachian region are very largely sandstones and shales and, to a considerable extent, of nonmarine de-

position, whereas those formed in the Mississippi basin are mostly of limestone and wholly marine. Eastern Ohio and southern Michigan, however, are allied to the Appalachian region.

In eastern and central Pennsylvania, the Mississippian is generally divisible into two groups, *Pocono* and *Mauch Chunk*. The former, which is the older, comprises gray sandstones and siltstones with remains of land plants and thin local coal beds. Coal from this horizon near Roanoke, Virginia, was used on the frigate *Merrimac* in her battle with the *Monitor*. The Pocono has thick members of sandstone and, in the anthracite field of east-central Pennsylvania, includes rather massive beds of quartz-pebble conglomerate; it is one of the prominent ridge makers in the Appalachian folds.

In marked contrast with this, the Mauch Chunk is composed of dull red sandstones and bright red siltstones and shales attaining a total of over 3000 feet in thickness. These beds bear "fossil" mud cracks and impressions of raindrops at many horizons. Fossils are exceedingly rare and comprise only fragmentary plant remains and a variety of amphibian footprints.

Traced westward, the Pocono group interfingers with fossiliferous marine zones in western Pennsylvania and gradually passes entirely into fine-grained marine sandstones and shales (Waverly group) in Ohio. It is evident that the Pocono represents a vast delta with its highest and thickest part in eastern Pennsylvania, where it reaches a thickness in excess of 2000 feet. There the coarser sediment derived from the east came to rest on the subaerial part of the delta, while the finer material was partly carried on to form the submarine foreset slopes farther to the west and southwest. The Mauch Chunk likewise represents the subaerial deposits of a low delta plain, but it formed under conditions of marked seasonal rainfall.

A maximum thickness of more than 8000 feet is attained by the Mississippian system along the border of Virginia and West Virginia (Fig. 148). Here the middle part is largely calcareous, but the lower and upper thirds are chiefly sandstones and shales of fluvial origin representing coastal plain or delta deposits.

At the northeast end of the geosyncline there was another basin of thick deposition in New Brunswick and Nova Scotia. In this, the Acadian area, the older strata are also nonmarine. The lower part, ranging from 2800 to 3100 feet in thickness, consists of coarse and poorly sorted detrital materials such as arkose, conglomerate, muddy sandstones, and micaceous shales. These constitute the *Horton group*. In age they correspond approximately with the Pocono group farther

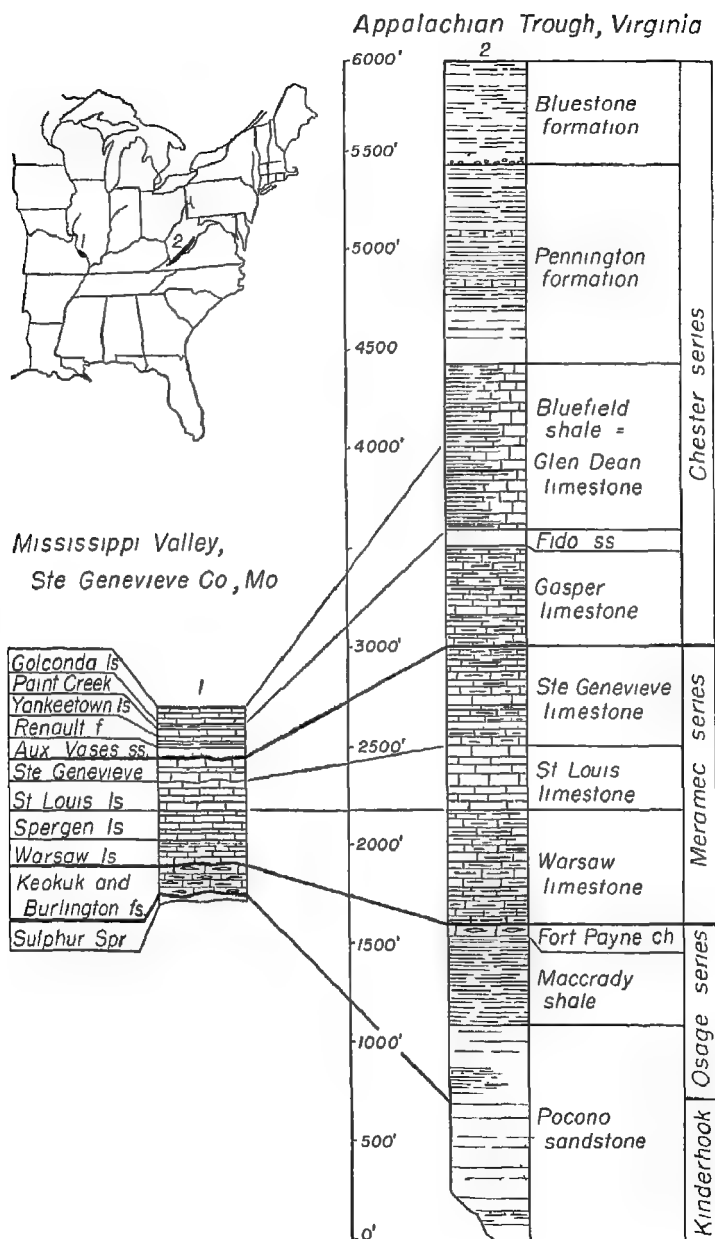



FIG 148 Columnar sections of the Mississippian system Left, a generalized section in the type area of the system in Ste Genevieve County, Missouri, right, a generalized section of the Appalachian trough in Virginia After Weller and Butts, respectively

south. In certain layers abundant fossilized stumps of small trees stand erect where they grew

The upper group in this region is known as the *Windsor* It is partly marine and includes red conglomerates, red and gray shales with thin beds of richly fossiliferous dolomite, and, locally, thick deposits of gypsum The total thickness is not less than 2000 feet The Windsor sequence extends northeastward into Newfoundland In age, as well as in conditions of deposition, it agrees with the Mauch Chunk

**Mississippi Valley.** In the Central Interior the Mississippian strata are predominantly limestone and have a normal thickness of 2000 to 2500 feet The section here is represented in Fig 148

The *Kinderhook series*, formed in the invading seas, varies greatly from place to place because of the local influence of terrigenous sediments from the submerging lands It includes sandstones, shales, and limestones which bear many local formation names A thin basal member of black, fissile shale (Chattanooga) is present over a very large southern area In eastern Tennessee, Kentucky, and Ohio, that is, east of the Cincinnati arch, this black shale thickens to over 100 feet and interfingers with the gray fossiliferous shales of the lower part of the Pocono group Gray shale or sandstone or limestone succeeds the Chattanooga shale to complete the Kinderhook series In northeastern Ohio this facies includes the *Berea sandstone,* one of the stones most widely used for carved trim

The succeeding *Osage series* reflects a clearing of the waters as the inundation reached its maximum It consists mostly of limestone and is remarkable for the amount of chert, which commonly occurs in the form of nodules or lenses in the limestone but locally replaces thick beds of the latter over considerable areas It bears the lead and zinc ores of the Joplin district of Missouri, Oklahoma, and Kansas, where it is very siliceous and is known as the *Boone chert*

The *Meramec series* consists of purer and less cherty limestones which locally pass into oolites on a scale unequaled at any other horizon in America The Salem limestone of Indiana, known to the building trades as *Indiana limestone,* is the most extensively quarried building stone in the United States Being soft and uniform in texture, it tools easily and is therefore much used for copings and exterior trim as well as for marble finish in lavatories There are probably few cities east of the Rocky Mountains that do not have some public buildings trimmed with this stone Most of it is supplied by the

enormous quarries about Bedford (Fig. 149), which place Indiana far in the lead among the states producing finish building stone. In the last two decades the annual output from these quarries has ranged between 1,000,000 and 1,500,000 tons.

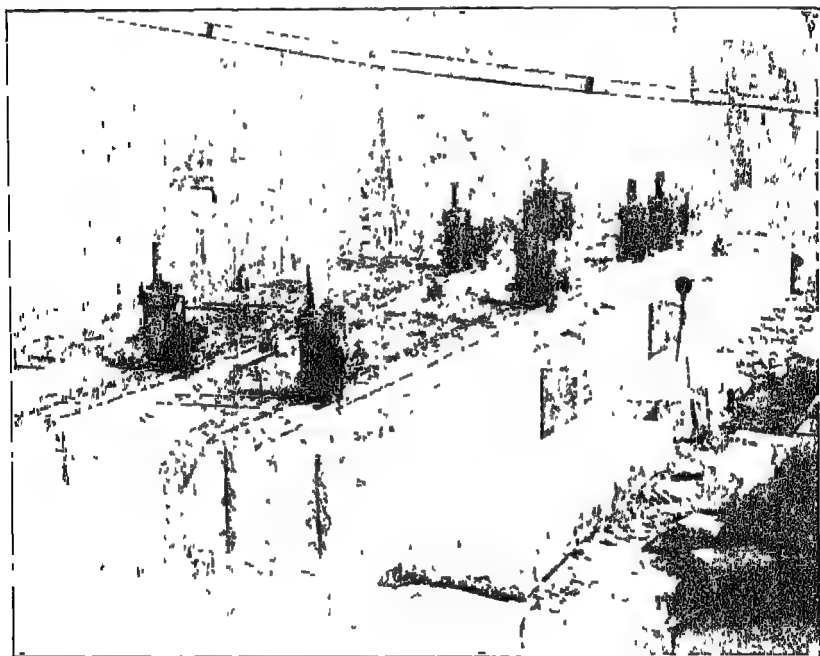
The most widespread member of the Meramec series is the *St. Louis limestone,* a purer and more compact stone which forms the conspicu-

*Indiana Limestone Company*

Fig. 149. Quarry of the Indiana Limestone Company in the Bedford oolite, near Bedford, Indiana.

ous bluffs of the Mississippi River near St. Louis and stretches continuously from Iowa to Alabama as one of the greatest sheets of limestone in this country.

The *Ste. Genevieve limestone,* next younger than the St. Louis, is likewise pure but inclined to be oolitic. It has suffered much underground solution where it floors large areas in the Ohio Valley. Mammoth Cave and thousands of others in the "Land of Ten Thousand Sink Holes" in Kentucky are excavated in this formation.

The *Chester series* is formed of alternating sandstones, shales, and limestones that have a combined thickness of 1000 to 1500 feet and

are grouped into more than a dozen formations in western Kentucky and Illinois. The spread of much sand and mud over the Mississippi basin at this time reflects, of course, uplift in southern Appalachia and Llanoria.

In the Ouachita trough, particularly, the latest Mississippian and early Pennsylvanian formations are very thick and almost wholly detrital. These sediments are thickest and coarsest in their southern exposures, where they form the Ouachita Mountains of Arkansas. This makes it clear that they were derived from Llanoria. Unfortunately there is still some uncertainty as to what portion of this vast wedge of detrital sediments belongs in the Mississippian system. In the Ouachita Mountains of Arkansas more than 2 miles of nearly unfossiliferous beds (Stanley shale overlain by Jackfork sandstone) lie between the Devonian and a very early Pennsylvanian horizon. These formations are made of dark detrital sediments with no limestones and little evidence of marine deposition. The sands in both are irregularly bedded and much rippled. Fragments of land plants are abundant but generally macerated. The sediments were obviously deposited over a low delta plain in front of a rising land mass. In the basal part of the Stanley formation there are three to five beds of tuff, ranging in thickness from 6 to 85 feet, indicating that the rising land bore active volcanoes.

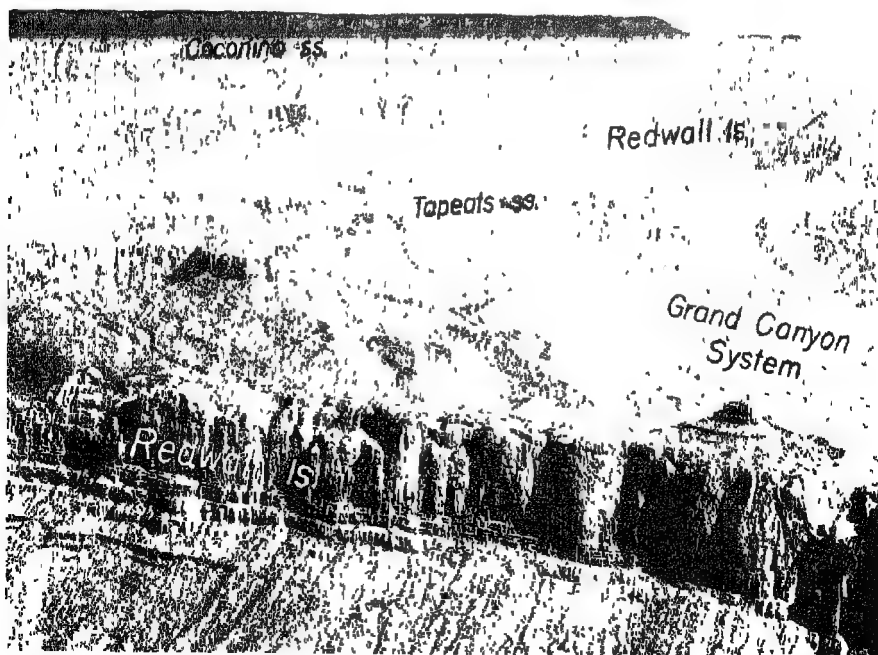
The fossil evidence of the age of the Stanley and Jackfork formations is inadequate. The very few marine fossils found are badly preserved and not very significant for exact dating. The more abundant land plants are generally too much macerated to permit exact identification. As the whole mass was later thrust northward upon rocks of a different province, it is now impossible to trace the Stanley and Jackfork into fossiliferous equivalents. Present opinion favors a very early Pennsylvanian age for these deposits. If this is true, then the marked uplift in Llanoria was delayed until the very close of the Mississippian period.

**Cordilleran Region.** Throughout the Rocky Mountain region the Mississippian system is represented by limestone, commonly massive and cliff-forming. Although it bears local names in different areas, it must originally have been a vast sheet of limestone strata stretching continuously from Nevada to the Black Hills, Yellowstone Park, and the Canadian Rockies. It is the cliff-forming *Redwall limestone* of the Grand Canyon (Fig. 150), and the *Madison limestone* of the northern Rockies. It reaches a thickness of 1200 feet in the vicinity

of Yellowstone National Park and continues far north into Canada This limestone is all of Early Mississippian age (Kinderhook-Osage)

The upper part of the Mississippian system is less well developed and less well known, but in parts of Utah, Nevada, and Idaho, and locally farther west, it is represented by thick masses of limestone In the Oquirrh Range south of Great Salt Lake, for example, the Mississippian formations, mostly calcareous, are approximately 6000 feet thick, and of this nearly 4000 feet is believed to be of Chesterian age Local formation names are used throughout the West, and a satisfactory synthesis is not yet possible

CARL O DUNBAR

*Fig 150 North wall of the Grand Canyon opposite Sunrise Point, showing the Redwall limestone cliffs midway between the basal Cambrian (Tapeats) sandstone and the Mid-Permian (Coconino-Kaibab) formations that rim the canyon The cliff in the immediate foreground is a spur of the south wall Pre-Cambrian Grand Canyon system may be seen dipping to the right below the Cambrian*

## Climate

The marine life gives no striking evidence of the climate of Mississippian time. The extraordinary abundance and variety of the crinoids in some of the formations, and the very extensive limestones, suggest temperate or warm water. It is a matter of surprise that reef corals were not common again as they were in the Middle Devonian, especially since Mississippian corals of reef-making types are known on the arctic coast of Alaska. However, since corals were never again prominent in the Paleozoic, it seems probable that their decline was due to factors other than climate.

The humidity over the lands certainly differed from region to region, and it likewise changed greatly in some regions during the period. For example, the nonmarine and brackish-water deposits of the Pocono sandstone contain so much organic matter that they are commonly gray or dark in color, and in places in Pennsylvania and West Virginia include thin beds of coal. These features clearly indicate swamps on a rather humid delta plain. In the same general region, however, the overlying Mauch Chunk redbeds have been thoroughly oxidized and with their abundant mud cracks and rain imprints bear evidence of extended droughts, suggesting a climate of marked seasonal rainfall. Evidence of considerable aridity is seen in Nova Scotia and Newfoundland, where the Windsor redbeds include extensive gypsum deposits and locally even salt, both of these being precipitates from the water of partially land-locked lagoons. In Michigan also there are red shales rich in brines which are the principal source of the salt manufactured in the Saginaw Valley.

In eastern Australia there is evidence of glacial conditions, as shown by the Kuttung series of volcanics and nonmarine, detrital sediments that are associated with varve clays and followed by tillites (Seaham).[5] The Australian geologists believe that this glaciation took place at some time during the Late Carboniferous (Pennsylvanian) period, but, since the Kuttung beds include fossil plants (Rhacopteris flora) that characterize the Lower Carboniferous in other continents, Schuchert thinks it more probable that the glaciation took place toward the close of the Lower Carboniferous.[6]

## Life of Mississippian Time

**Marine Invertebrates.** Marine animals are still much better known than the land life of this period, for the continental sediments accu-

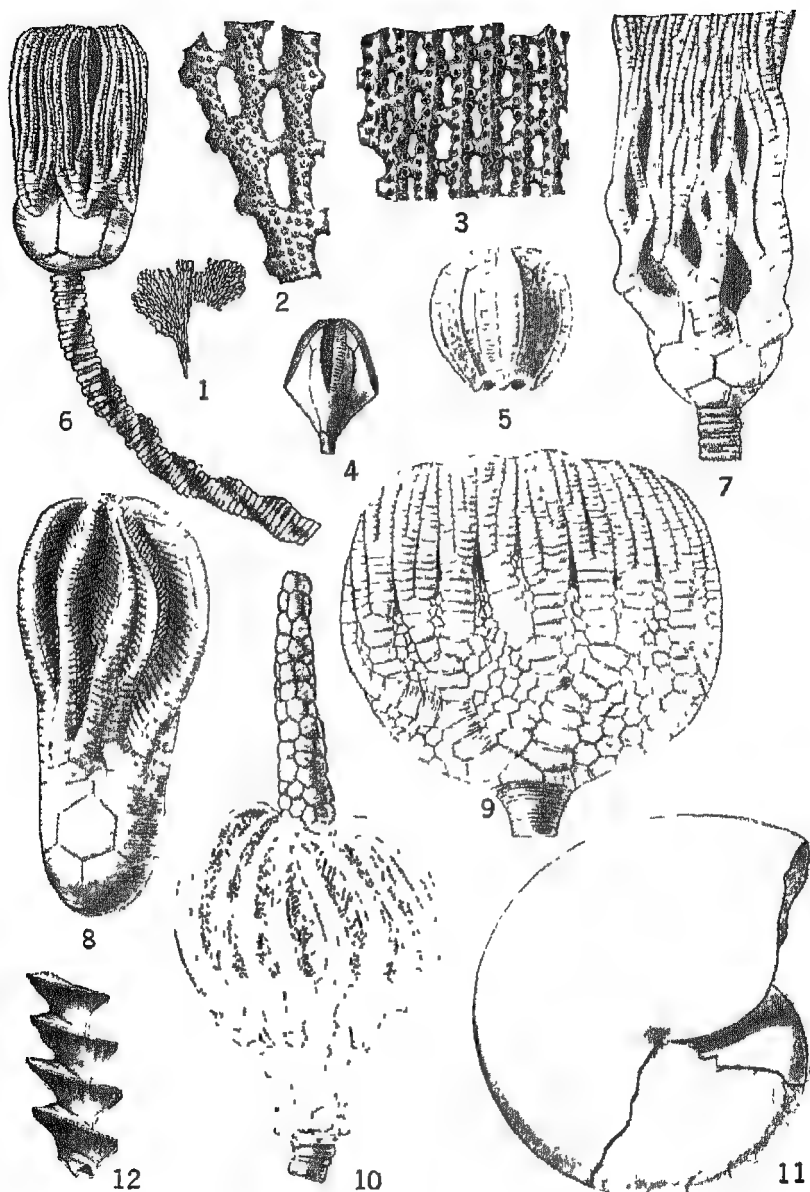



Plate 9 Mississippian Bryozoa (1–3, 12), Blastoids (4, 5), Crinoids (6–10), and Ammonite (11)

Figs 1, 2, *Polypora cestriensis* (×⅔ and ×6), 3, *Fenestella cingulata* (×6), 12, *Archimedes wortheni*, the screw-like axis of a colony, 4, *Pentremites pyriformis;* 5, *Cryptoblastus pisum,* 6, *Platycrinites hemisphericus,* 7, *Cyathocrinus multibrachiatus,* 8, *Agassizocrinus dactyliformis,* 9, *Forbesiocrinus wortheni,* 10, *Batocrinus pyriformis,* 11, *Imitoceras rotatorius* All natural size except Figs 1–3 Drawn by R G Creadick

mulated under conditions poorly suited to the preservation of fossils, whereas the shallow, limy sea floors harbored life of the greatest luxuriance

Although clearly evolved from Devonian life, the Mississippian faunas were given a distinctive character by the decline of such groups as the corals and trilobites and the great expansion of others like the echinoderms, the lacy bryozoa, and the spiny brachiopods

FIG 151. The melon echinoid, *Melonechinus* Part of a slab of limestone near St Louis, with several specimens partly embedded in the matrix These echinoids are about the size of a small cantaloupe, which they resemble in shape

Echinoderms flourished as never before *Crinoids* (Pl 9, figs 6–10) grew in such luxuriance that their dismembered plates contributed largely to the making of thick crinoidal limestones, some of which have a large areal extent No other geologic system has yielded such a variety or such numbers of well-preserved specimens of this class *Blastoids* (Pl 9, figs 4, 5) were also at a climax, the typical bud-shaped species (genus *Pentremites*) being particularly characteristic of this time Starfishes appear to have been rare, but sea-urchins of a few kinds were locally abundant The most striking of these were large melon-shaped echinoids (*Melonechinus*, Fig 151) found chiefly in the St Louis limestone

The *Foraminifera* for the first time assumed an important role as rock makers A single type, *Endothyra*, occurs so abundantly in the

Salem (Bedford) oolite that the formation locally takes on the character of a foraminiferal limestone This genus is comparable to the modern *Globigerina* in size, but it probably did not float, as that genus does, and probably did not form foraminiferal ooze on the deep sea floor

*Corals* persisted throughout the period but generally were neither varied, reef-making, nor especially common The most conspicuous

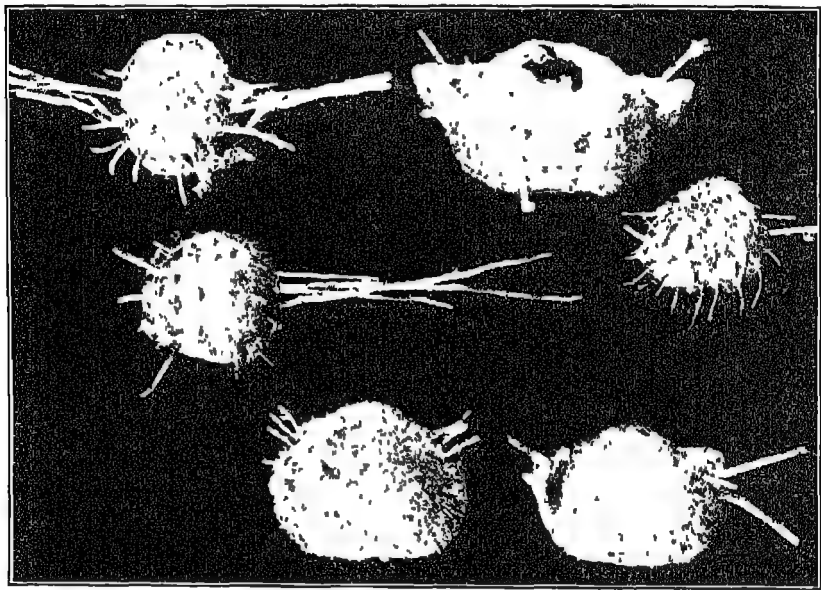



Fig 152 Productid brachiopods These are Permian species etched free of the stone Similar forms were common in the Mississippian seas

type in the interior seaways was a compound tetracoral (*Lithostrotionella*) that, during the St Louis epoch, formed "heads" as much as 2 feet across On the other hand, we must note the complete absence of the honeycomb coral (*Favosites*), which was so conspicuous in the Devonian reefs

*Bryozoa* were again very numerous, and the lacy types (fenestellids) now reached their greatest variety Among these the genus *Archimedes*, with its thickened and spirally twisted axis, is most distinctive (Pl 9, fig 12)

*Brachiopods* continued to be the dominant kind of "shellfish," and many of them were much like the Devonian forms, differing only in specific details, but the climactic expansion of the spiny-shelled forms

of the tribe of *Productus* (Fig 152) gave a different aspect to the fauna as a whole So common were these species in this and the two following periods that the inundations of the Late Paleozoic have been called the *Productus seas*

*Molluscs* continued in considerable variety, and in the sandy sediments of the Pocono group small clams and gastropods are locally more common than any other fossils. The Salem oolite includes a large number of tiny snails Perhaps the most significant molluscan advance is among the *goniatites* (Pl 9, fig 11), these primitive ammonites were much more common in Europe, however, than in America

Trilobites had already declined almost to extinction, and the remaining species were small and rather rare No trace of insects has yet been found, though the high development of that group in the next system suggests strongly that they were actually present in Mississippian time

*Yale Peabody Museum*

Fig 153 Modern shell-crushing sharks Above, the living bull-head shark, *Gyropleurodus francisci*, from the Gulf of California, below, skull of the closely similar Port Jackson shark of Australia, showing the jaws paved with blunt teeth which serve to crush the shells of molluscs These fish range from two to three feet in length

**Vertebrates.** *Fishes* were locally abundant, though less varied apparently than they had been in the Devonian The best-known group is the shell-crushing sharks, whose blunt, "pavement" teeth and fin spines alone are preserved (Fig 153) This apparently was their heyday, for nearly 300 species are known from the Mississippian rocks but only 39 from the preceding and 55 from the following system Since their modern descendant, the living Port Jackson shark, feeds upon crustaceans and certain shellfish, it is not improbable that the rise of the shell-crushing sharks in the Devonian and their success in the Mississippian contributed to the decline of the trilobites

*Land animals* left an indisputable record in the form of numerous footprints, and in 1941 actual skeletal remains were found in the Mauch Chunk beds in West Virginia [7] In Europe, also, the skeletons

of small, salamander-like amphibia have been found The footprints are most common in the redbeds of the Mauch Chunk, where they are associated with mud cracks and rain imprints Doubtless many of these record the tragic search for water as the vanishing mudholes gave way to barren flats during the summer droughts Yet among them there may be the hallmarks of destiny, for some of these restless creatures, driven by their extremity, were to develop agility and freedom from the water that would enable them in the coming ages literally to inherit the Earth

**Land Plants** Land plants were, of course, as abundant as in the Late Devonian, but their remains are lamentably broken and macerated in the deposits available to us So far as is known, they were much like those of the Pennsylvanian, which will be described in Chapter 12

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A fine summary

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# Chapter 12

# THE PENNSYLVANIAN PERIOD

It is fitting that this great coal-bearing system should be named for the chief coal-producing state in America and the one where it was first comprehensively studied Here also the coal floras are found in greatest variety, though the best marine sequence occurs in mid-western states from Nebraska and Kansas to Texas.

## Physical History of North America

### *Coal Swamps of the Eastern Interior*

At the beginning of this period the central interior of the United States was a vast lowland hemmed in on the south and east by the mountainous borderland of Llanoria and Appalachia (Fig 154) The Canadian Shield was apparently a plain of low relief stretching away to the north, while borderlands of undetermined extent and relief formed the western margin of the continent

Early Pennsylvanian formations are restricted almost entirely to the geosynclinal areas, as indicated in Fig 154*A* The sea entered the Cordilleran trough from the southwest, and there the deposits are marine and mostly limestone Another seaway reached the Ouachita trough via Mexico and Texas and pushed eastward along the north side of Llanoria Subsidence was rapid here all the way from Texas to West Virginia, but the marginal highlands supplied mud and sand in such quantities that the trough was filled to sealevel most of the time as far west as Oklahoma Over the subsiding lowland thus maintained, great swamps developed in which vegetation accumulated to be transformed later into the phenomenally rich coal deposits of Alabama and West Virginia

Before the middle of the period submergence spread northward over most of the central and western states (Fig 154*B*), and the sea reached temporarily to the foothills of Appalachia, covering, at a maximum, approximately 30 per cent of North America. Even then, however, the heavily loaded streams from the east were struggling to crowd

*Fig 154A (left) Early Pennsylvanian (Lampasan) paleogeography Land surface lightly shaded Black line shading in Appalachian trough marks dominantly nonmarine deposits*

*Fig 154B (right) Early Middle Pennsylvanian (Desmoinesian) paleogeography Symbols as above This represents the maximum submergence of the period.*

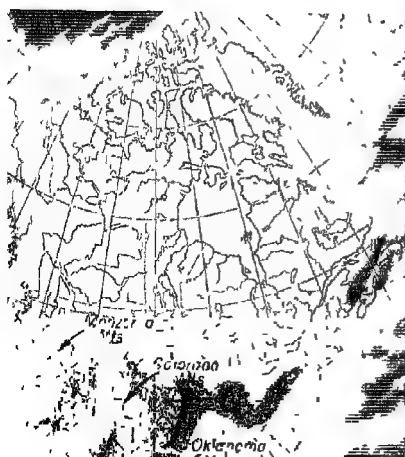



*Fig 154C (left) Late Pennsylvanian (Early Virgilian) paleogeography Symbols as above*

back the sea and to build out broad alluvial plains. Slight subsidence repeatedly brought the shoreline far to the east, only to retreat again as the shallow sea was filled and transformed into swampy lowland. The marginal lands were repeatedly uplifted, while the broad interior basin slowly sank until its pre-Pennsylvanian floor lay from two thousand to several thousands of feet below the surface. Meanwhile filling kept close pace with subsidence all the way from Pennsylvania to Kansas and Nebraska.

In the vast swamps thus repeatedly formed, vegetation accumulated to form coal. In part the swamps were marginal to the sea, but in part they were formed by irregular warping far from shore. Within this far-flung lowland, subsidence was most rapid along the Appalachian and Ouachita geosynclines and in the Illinois basin, and in these areas the Pennsylvanian system is several thousands of feet thick. A small basin in Rhode Island may have been completely isolated from the rest as an intermont trough. At the north end of the old Appalachian trough lay the Acadian basin, in which thick nonmarine deposits were formed that contain the important coals of Nova Scotia, Cape Breton, and New Brunswick. This basin extended also into Newfoundland and probably drained northeastward into the Atlantic.

### *Varied Conditions in the West*

The rising mountains in Oklahoma and Colorado (see below) introduced varied conditions in the western states. At times of greatest submergence they stood as islands in the sea, and even when the sea was far away they were flanked by structural basins in which nonmarine sediments accumulated over wide alluvial plains. A marine embayment persisted throughout much of the period over parts of Utah and Nevada.

### *Crustal Unrest*

Uplift and mountain making were not confined to the beginning and the end of this period; it was, throughout, a time of much crustal warping and of repeated local disturbances, with folding in the marginal lands and in the Mid-Continent as well. This we know from the character of the sediments. If Appalachia had remained stable, the basal conglomerates of the Appalachian basin should have given way to finer and finer sediments as the relief of the highlands was brought low. Such, however, is not the case, for sandstones alternate

with shales and locally give way to conglomerates in the upper as well as the lower part of the system. Limestones are rare, thin, and usually impure east of the Mississippi River. Without repeated rejuvenation, the borderlands could hardly have supplied the enormous thickness of the formations, which nearly everywhere exceeds 3000 feet, amounting to 9000 feet in Alabama, more than 20,000 feet in Arkansas, 15,000 feet in Oklahoma, and 13,000 feet in Nova Scotia

**The Acadian Highlands** In the Maritime Provinces of Canada there are five unconformities in the Pennsylvanian succession, each corresponding to local uplift Here the depositional basins were intermont troughs produced by block faulting In some places this movement involved only broad regional warping, but in others even the sediments in the basin were locally folded Farther south no particular episodes of deformation have been determined, but in Alabama it is evident that Appalachia stood almost as high throughout the Pennsylvanian as it did at the beginning of the period

**Uplift in Llanoria; The Oklahoma Mountains** During the closing stages of the Mississippian period or, more likely, at the very beginning of the Pennsylvanian (depending on the age of the Stanley-Jackfork deposits of Arkansas and Oklahoma), there was marked uplift in Llanoria, whence rapid erosion brought a vast amount of detrital material into the Ouachita geosyncline As if to compensate for this uplift, the geosyncline subsided steadily and so formed a trap to catch the sediments which accumulated to a thickness of more than 15,000 feet (23,000 feet in Arkansas) during the period

During the initial phases of this movement the deformation and uplift were wholly in the land mass south of the geosyncline, where compressive forces were exerted from the region which is now the Gulf of Mexico But at a later stage, still early in the Pennsylvanian period (Atoka time), the floor buckled along the northern margin of the geosyncline to form a series of ranges of domed mountains along the southern border of Oklahoma and across the Panhandle of Texas These have been named the *Oklahoma Mountains* They include the Arbuckle and Wichita mountains of Oklahoma and the buried Amarillo Mountains of Texas (Fig 155) They arose out of the Pennsylvanian sea as rather simple arches accompanied by numerous normal faults Suffering active erosion as they rose, they were flanked by their own debris, while the downwarped areas about them trapped the sediment that continued to pour into the geosyncline from the hinterland, Llanoria Their topographic relations were thus some-

what like those of the mountainous Shantung peninsula, which now rises out of the surface of the great Hwang-Ho delta in China.

These ranges probably did not attain a great height above the sea, but they were repeatedly uplifted as they were eroded, and the floor immediately adjacent continued to sink, until Pennsylvanian formations accumulated which still are more than 12,000 feet thick in the Ardmore basin just south of the Arbuckles and also in the Anadarko basin to the north. If these strata were now stripped away, the Arbuckles would tower above their base as a range of mountains more than 2 miles high. They never stood so high above the surrounding surface, however, because the adjacent area was subsiding while they rose and they were largely buried in their own debris. The history of the Wichita and the Amarillo mountains is essentially similar. They are approximately parallel to the Arbuckles and are related in time and in structure. It now appears that there were at least two major pulses in their uplift, one early in the Pennsylvanian and another near the middle of the period.[1]

FIG. 155. Sketch map showing the location of late Paleozoic mountains in the Mid-Continent region. Data in part from Ver Wiebe, from Powers, and from P. B. King.

**The Colorado Mountains.** Throughout Pennsylvanian and Permian times, as well as in the early Mesozoic, a group of uplifted areas in Colorado and near-by states profoundly influenced the formations deposited in the Rocky Mountain region. The Pennsylvanian formations are thick and almost entirely detrital near these old ranges, becoming finer grained and more calcareous in all directions from the uplifted areas. It appears evident that these ranges were of mountainous height or were repeatedly uplifted in order to supply the great bulk of detrital sediments that flank them. At least four orogenic

units are recognized and individually named (Fig 155). The entire group has been designated the *Colorado Mountains* *

**Marathon Disturbance and the Close of the Period.** Near the close of the period a range of fold mountains was thrust up out of the sea in western Texas, accompanied by northward thrusting that car-

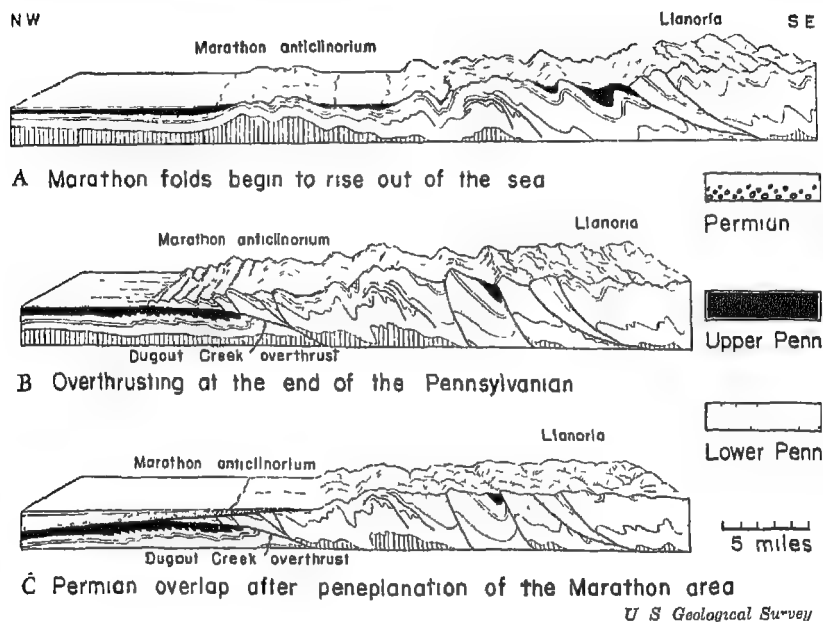



FIG 156 Three stages in the history of the Marathon orogeny The section runs from northwest to southeast across the Marathon folds and includes a part of Llanoria, the Paleozoic land mass that has since been reduced by erosion and buried under the Cretaceous deposits of the Gulf Coastal Plain Adapted from Philip B King

ried Devonian and Ordovician formations up over the Pennsylvanian These structures are now clearly exposed in the Marathon basin of

* The name *Ancestral Rockies* was introduced for these mountains by Willis T Lee in 1918 and has since gained considerable usage It unfortunately carries a connotation of genetic relation to the present Rockies that is not justified These Paleozoic structures differed in their trend from the modern ones and were later submerged and deeply buried during the latter half of Mesozoic time The forces that built the Rockies were probably unrelated in genesis and certainly separated by a hundred million years or more in time from those responsible for the Paleozoic mountains Our experience has shown that the use of Lee's name invariably leads to confusion of the true relations, and in 1933 we therefore proposed the geographical name *Colorado Mountains*, since the uplifts were largely (though not entirely) confined to that state

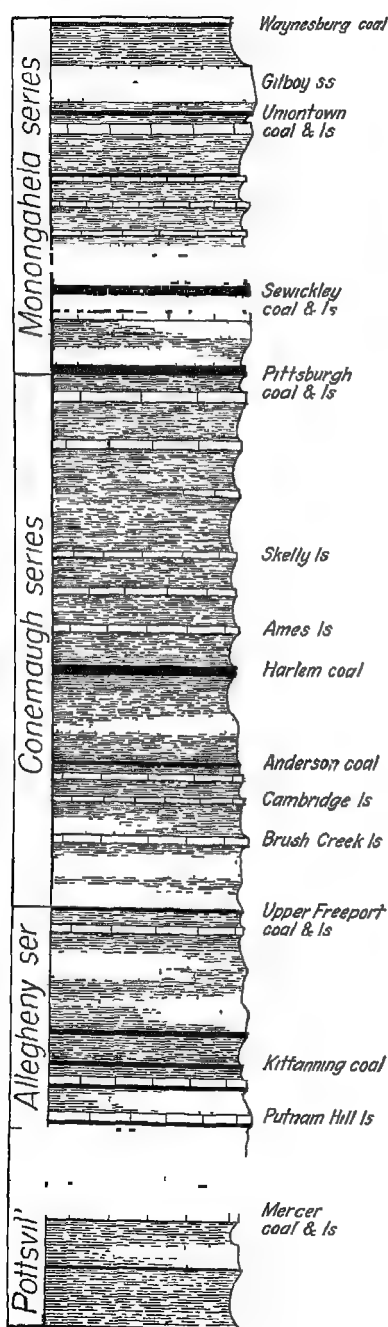
Trans-Pecos Texas, and the disturbance has been named for this region (Fig 156)

The Marathon area was within the Ouachita geosyncline during Pennsylvanian time, and the very thick record of this period shows that marked uplift occurred repeatedly in Llanoria a short distance to the south For example, there are numerous beds of conglomerate in the Marathon basin, some of them of exceptional coarseness, containing rocks that could only have come from the near-by south It was not till the close of the period, however, that the compression reached northward with such force as to crumple and close-fold the rocks of the geosyncline As a result of this disturbance, the Pennsylvanian and older formations were folded, faulted, and uplifted, and later were truncated by erosion so that here the Permian strata overlie them with profound unconformity The disturbance was less intense to the north and west of this area, but an angular unconformity is common between the Pennsylvanian and Permian as far west as El Paso Most of the disturbed area in Texas is now covered by Cretaceous rocks

### *Close of the Period*

Near the close of the Pennsylvanian there was a marked retreat of the interior sea toward the west, and the continent was largely if not completely emergent for a time Western Texas and southern New Mexico were then in the throes of the Marathon orogeny, but over much of the Central Interior the late Pennsylvanian emergence was due to continental uplift which resulted merely in nondeposition with no marked deformation in the Pennsylvanian deposits As a result, great difficulty has been experienced in drawing an exact boundary line between the Pennsylvanian and the Permian systems in parts of the United States

In various parts of the world, however, there was extensive orogeny at this time (Fig 147) The Armorican ranges of Europe, initiated at the end of the Mississippian, experienced marked rejuvenation during and at the close of the Pennsylvanian In fact, the culmination of Late Paleozoic mountain making occurred at this time and during the Early Permian The effects of this orogeny are to be seen in the stumps of the ancient mountains in southern Wales and England, in the central plateau of France, in the Harz and Black Forest regions of Germany, and in Bohemia, likewise in the Spanish Meseta, Corsica, and Sardinia In the Himalaya region, this was a time of great mountain making, "a great revolution in the physical geography of India," which during Pennsylvanian time blotted out the inland

Fig 157 Section of the Pennsylvanian system in eastern Ohio (Muskingum County), showing repeated alternations of coal, sandstone, shale, and thin limestone Vertical scale 1 inch = 150 feet

(Tethyan) sea In the Urals also, as in eastern Australia and the Andean region, there was disturbance at this time In most parts of the world, however, the areas of Late Pennsylvanian orogeny suffered even greater disturbance during or at the close of the Permian

## Stratigraphy of the Pennsylvanian System[2]

**Appalachian Coal Fields.** In the Appalachian basin, sandstones and shales make up nearly the entire thickness of the Pennsylvanian formations, though conglomerates occur at various levels, especially near the eastern margin (Fig 157) The sandstones and conglomerates are commonly lenticular and cross-bedded, lensing in and out among the shales so that it is usually difficult to follow a definite horizon for many miles The color is generally gray or dark because of the carbon of included organic matter, though in some places red-beds alternate with the gray The dark sediments include abundant remains of land plants Coal beds occur at many horizons, some of them thick enough to mine, others not It is evident that these sediments were deposited by streams on a swampy lowland At occasional intervals, however, there are

*Fig. 158. Fossil tree trunks standing as they grew. Specimen at the left, from The Joggins, Nova Scotia, that at the right, showing 8 feet of trunk, from Table Head, Great Bras d'Or, Cape Breton.*

thin beds of impure limestone or of calcareous shale, bearing marine fossils, which represent temporary inundations of the lowlands by the sea. The marine limestones, though thin, are persistent over large areas in contrast with the varied fluvial deposits. They form important key horizons for correlation and the determination of structure. In general, they are most numerous, most regular in sequence, and of widest spread in the western part of the basin, for they tend to wedge out and disappear toward the east.

In the coal basin of Nova Scotia and New Brunswick, where the Coal Measures reach a thickness of a few thousand to 13,000 feet, marine horizons are wholly absent. The section exposed in the sea cliffs at The Joggins near the head of the Bay of Fundy is of special interest because of the stumps and trunks of trees buried in the position of their growth (Fig. 158). Here erect trunks are recorded at 20 horizons distributed at intervals through about 2500 feet of beds. Many of the preserved trunks are several feet high, some exceeding 20 feet. They show clearly how rapid the deposition of individual beds must have been, since they were in each case buried before the stumps had time to decay. It is evident, however, that deposition

of sediment at any locality was intermittent, since these trees, some of them as much as 4 feet in diameter, must have grown unhindered before their burial. Deposition appears to have been by sluggish, meandering streams that frequently deserted their sediment-choked channels to burst out in new courses over timbered lowlands. (Compare Fig. 27, p. 46.)

**Illinois Coal Fields.** The Illinois field is closely allied to that of the Appalachian basin. The two were originally continuous in the southern part and shared in common deposition, but have since been isolated by later uplift and erosion along the Cincinnati arch. In general, the sediments are finer of grain in Illinois, and marine shales assume much greater importance than in the East. There are a number of widespread coal beds, however, some of which appear to have extended over most of the state and eastward into Indiana. A limestone "cap rock" occurs a short distance above nearly every one of the coals; these vary in thickness from several inches to a few feet and are as widely persistent as the coal beds, the repeated occurrence of these marine horizons above the coals emphasizing the cyclic nature of the deposition in this region. Each coal is the residue of vegetation that grew here while the region stood as a swampy lowland. The cap rock of limestone shows that the sea followed, inundating the swamp. Marine shales follow the limestone, grading up into nonmarine shales and sandstone that were formed as the sea was filled up and driven back. Local unconformities occur at the horizon of the transition, marking places where the extended streams cut channels in the shale and filled them with sand.

**Mid-Continent Region.** The coal fields of Missouri and Kansas, like those of adjacent parts of Nebraska and Iowa, present a section of 2000 to 3000 feet of beds in which limestones and shales alternate repeatedly, while sandstones and siltstones occur at greater intervals (Fig. 159). Here the limestones comprise about 25 per cent of the section and sandstones generally less than 10 per cent. Many of the shales and siltstones bear no fossils except fragments of land plants, and were probably deposited on low delta plains. The limestones, on the contrary, like certain of the shales, have abundant marine fossils. In this region many of the thin units persist with little change over great distances, bearing witness to uniform conditions of deposition over great areas. Repeated alternations of marine and nonmarine beds indicate that deposition was approximately at sealevel and suggest that the marine waters were extremely shallow.

Traced southward into Oklahoma and Arkansas, the entire system changes gradually but profoundly as we enter the Ouachita geosyncline and approach Llanoria. There the section thickens to 12,000 or even 23,000 feet, sandstones and siltstones assume great prominence, while the limestones thin and in many cases grade laterally into sandstone or shale. In short, the thickness of the Coal Measures in the Ouachita geosyncline is fully five times that of the northern Mid-Continent fields. This has resulted in part from the more rapid deposition in the geosyncline where subsidence allowed the sediment to come to rest, in part from the nearness to Llanoria, which was supplying much of this material, and in part from the fact that deposition began first in the geosyncline and gradually overlapped northward.

*Carl O. Dunbar*

FIG. 159. Oread formation, consisting of alternating members of limestone and shale, at Lawrence, Kansas. A characteristic outcrop of the Pennsylvanian strata in the Mid-Continent region.

In central and western Texas the Pennsylvanian formations are several thousands of feet thick, and here also the influence of Llanoria may be seen.

Deep drilling has shown that Pennsylvanian formations extend west of their outcrop under nearly all the Great Plains. They are exposed in the Black Hills and in the hogbacks flanking the front of the Rockies, as well as about many of the ranges farther west.

**Cordilleran Region.** Throughout the Cordilleran region there is so much local variation that brief description is impossible. Along the front of the Rockies, in Wyoming and Colorado, where these formations overlap on Pre-Cambrian granite, the lower part (Fountain formation) is arkosic and red. The upper part also (Lyons formation) is largely red and generally sandstone and shale. In the vicinity of Colorado Springs these rocks are much cross-bedded, unfossiliferous, and wholly nonmarine, but toward the northeast they

grade in part into calcareous and marine deposits (Ingleside of Wyoming and Minnelusa of the Black Hills) Farther west in Colorado, also, there are fossiliferous marine sections In northeastern Utah is the Oquirrh formation, with the astonishing thickness of more than 15,000 feet of lenticular quartzites and limestones, and but little shale The lower several thousand feet of this deposit is of Pennsylvanian age, but the upper part is Permian In extreme western Colorado and east-central Utah the Paradox formation, supposedly of Pennsylvanian age, includes a great thickness of *salt,* which apparently interfingers laterally with dolomite Here is striking evidence of local aridity that stands in marked contrast with the coal swamps of the East It may represent a local condition in the rain shadow of the western range of the Colorado Mountains

The great amounts of detrital sediment and the local variations in the Pennsylvanian rocks of the Cordilleran region stand in striking contrast with the far-flung limestones of the underlying system and bear witness to the disturbances that began in this region about the close of Mississippian time

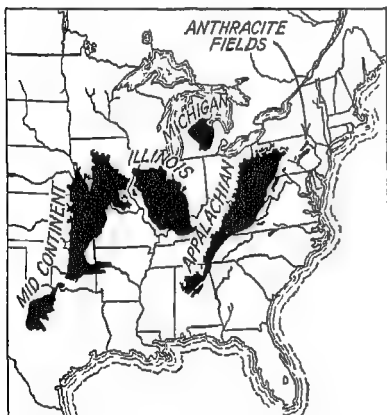



Fig 160 Map showing the coal fields of Pennsylvanian age in eastern United States

## Economic Resources

**Coal** It is no accident that in many parts of the world the Pennsylvanian rocks are known as the "Coal Measures" Although coal has formed locally during every period since the spread of terrestrial vegetation in the Devonian, no other system contains so much *high rank* coal In these formations lie the great coal fields of the British Isles, of France (Saar basin), of Germany (Ruhr basin), and the smaller fields of Belgium and Silesia, and of the Donetz basin of Russia, likewise the chief coal fields of North America. These fields, together, produce more than 80 per cent of the world's coal Some of the younger systems (Jurassic and Cretaceous) may hold even greater reserves for the future, but the younger coals are generally inferior in quality and can not extensively compete with the Paleozoic coals in the world markets

In America the coal fields of Pennsylvanian age occupy an area estimated to exceed 250,000 square miles, a figure considerably greater than that of the coal fields of any other continent. They lie almost entirely in the eastern half of the United States, the chief exception being the small Acadian basin of the Maritime Provinces of Canada (Fig. 160).

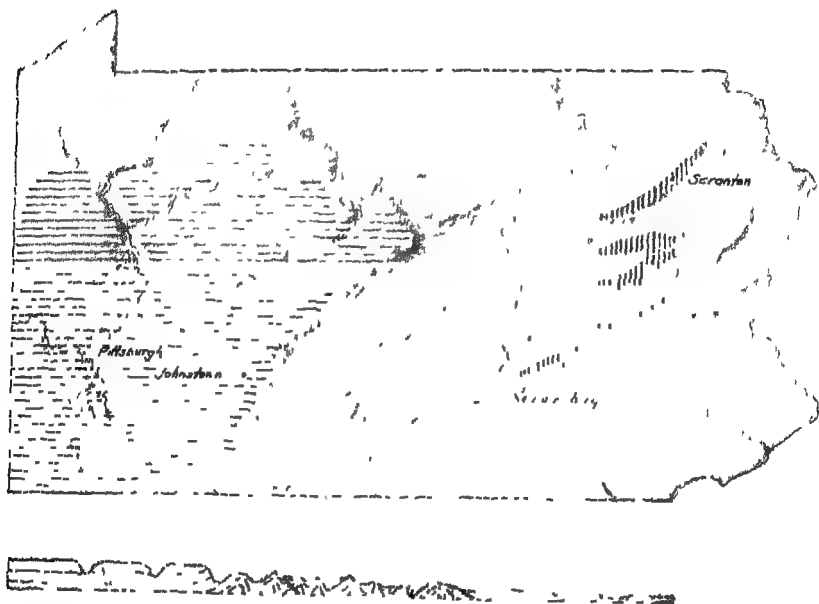



Fig. 161. Coal fields of Pennsylvania. The anthracite fields (*vertically lined*) are synclines in the folded zone. The bituminous fields (*horizontally lined*) are in the flat-lying rocks of the Allegheny Plateau.

Of the five well-defined fields shown in the figure, the *Anthracite field* of eastern Pennsylvania is in some respects the most interesting. Although less than 500 square miles in area, it has produced to date almost one-fourth of the total output of coal in North America. Its production reached a peak of 93,000,000 tons in 1923 and has averaged over 85,000,000 yearly for the last quarter-century. Unfortunately more than half of the coal has already been mined, and the supply of anthracite bids fair to be exhausted during the life of the present generation.

The anthracite field is in reality but an eastern part of the vast Appalachian basin that was caught in the Permian folding, and isolated from the rest by later erosion that destroyed all the Coal

Measures in eastern Pennsylvania except those parts preserved in deep synclinal folds (Fig 161) This folding and the resulting pressure converted the bituminous coal into the hard anthracite by eliminating the volatile matter. The thickness of some of the anthracite beds is noteworthy The most remarkable bed is the Mammoth, which extends throughout the field, with an average thickness of 35 to 40 feet and in one place a thickness of 114 feet due to overfolding (Fig 162)

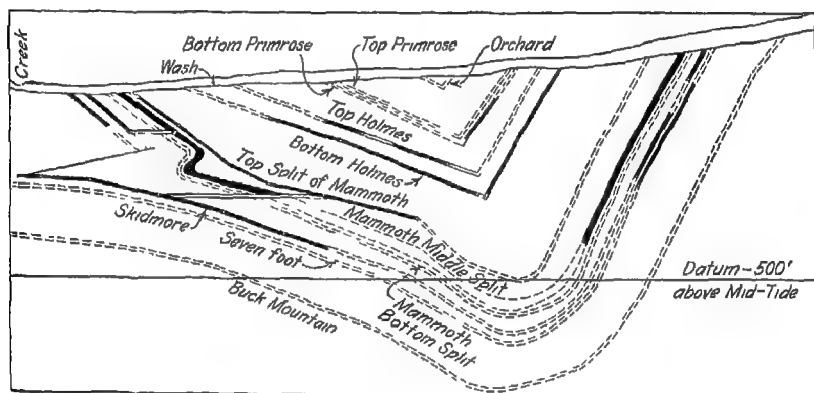



FIG 162 Cross-section of a fold in the South Anthracite coal basin, after Kemp The Mammoth coal bed is separated by interbedded shale into 3 distinct beds, each known as a "split" of the Mammoth coal

The *Appalachian field* is the second largest, and much the greatest producer of the several coal regions It underlies the Allegheny Plateau and extends from northern Pennsylvania to Alabama Pennsylvania and West Virginia are the heaviest producers, but Ohio, Kentucky, and Alabama also yield much coal This field alone furnishes almost one-fourth of the world's coal supply

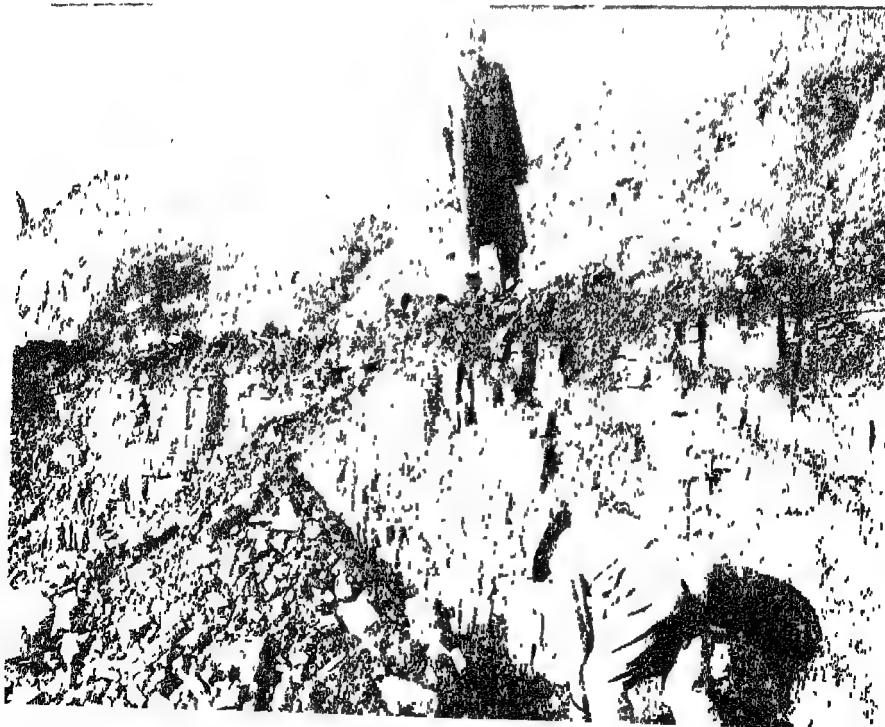
Throughout most of this area the strata lie quite flat, and the coal is bituminous, occurring at many levels About 60 beds are recognized in Pennsylvania, but of these only 10 are widely mined, the rest being too thin to work profitably The most remarkable of these beds is the Pittsburgh coal (Fig 163), which is more than 13 feet thick about Pittsburgh and is known to be workable over an area of 6000 square miles in western Pennsylvania, eastern Ohio, and northwestern West Virginia, where it is estimated to contain more than 22,000,000,000 tons of coal Up to 1926 it had yielded approximately 3,500,000,000 tons of coal, with a value at the mines more than twenty times that

of the gold produced by the greatest gold mine in the United States [1]

The *Illinois field* is a shallow structural basin extending into southwestern Indiana and western Kentucky It includes 10 or more important producing horizons and ranks second to the Appalachian field, far outstripping the much larger Mid-Continent region in production The coal beds here do not attain so great a thickness as they do farther east, but some of them, notably the Herrin coal, persist with remarkable uniformity over much of the state of Illinois

The *Mid-Continent field* embraces the coal fields of Missouri, Iowa, Kansas, Oklahoma, and northern Texas Although the area exceeds that of the Appalachian field, the output of coal has been less than one-tenth as great Here the beds are commonly less than 4 feet thick, and the best producing horizons are in the lower part of the system There are extensive areas where the surface is flat and the

U S BUREAU OF MINES, PITTSBURGH

*Fig 163 Outcrop of the Pittsburgh coal seam near Pittsburgh, Pennsylvania*

coal so near the surface that it is mined by stripping with steam shovels.

The remaining fields are relatively small producers, together supplying less than 1 per cent of the world's coal. In the tiny Rhode Island basin extreme metamorphism has reduced the coal to graphite, or so nearly so that it has little fuel value.

Most of the Pennsylvanian coals of the United States include sulphur as an impurity. This is believed to indicate that the coal swamps bordered the inland seas and were brackish, since sulphur-depositing bacteria live in the sea but do not thrive in fresh-water lakes and swamps. Conversely, the slight amount of sulphur in the anthracite of eastern Pennsylvania and in the coals of the Acadian basin indicates for these regions swamps entirely of fresh water.

**Petroleum and Natural Gas.** Pennsylvanian rocks have been an important source of petroleum and natural gas in the Mid-Continent oil fields, and for a number of years, from the discovery of these fields in the 1890's until about 1925, constituted their only important producing horizon. During that time Kansas and Oklahoma produced from these beds over 2,000,000,000 barrels of oil. Subsequently, however, production has been found at greater depths in the Ordovician "sands," which have given the spectacular developments of recent years in those two states and in north-central Texas.

## CLIMATE

The terrestrial sediments with their plant remains speak eloquently of warm, moist climate during the chief coal-producing stages of the Pennsylvanian in many parts of the world. The vegetation of the coal beds clearly grew in swamps, where it accumulated under standing water, as evidenced by the spreading root systems still preserved in the fire clays that underlie the coals in many places. Moreover, the structural types of the foliage so well preserved in the roofing shales at many places indicate marked humidity. Swamp waters are required to protect the fallen vegetation from the air and thus save it from decay. The wide distribution and the repeated occurrence of coals therefore assure us that there was a persistently moist climate over vast regions of the Pennsylvanian landscape.

This does not prove, of course, that no parts of the Earth were arid. It is well to remember that at present the dripping jungles of the Amazon Valley are separated only by the narrow Andean chain from

the desert coast of western Peru. Similar extremes probably existed on the continents during Pennsylvanian time, for lofty mountains must have been accompanied, then as now, by a leeward rain shadow of deficient rainfall. The salt deposits of the Paradox formation in eastern Utah and western Colorado, like the red arkose of the Fountain formation of central Colorado, may indicate such local aridity about the Colorado Mountains. On the contrary, the coal swamps of the eastern interior were formed where the warm, moist winds were rising up the long western slope of Appalachia. In general, it appears that humid climatic conditions were exceptionally widespread during Pennsylvanian time.

There is also much evidence that the climate was warm, even in high latitudes, during much of the period. The mere presence of abundant vegetation is no evidence, for it is well known that the most extensive modern accumulation of peat is in subarctic regions where slow growth is more than counterbalanced by slow decay, but the *character* of the Carboniferous vegetation indicates a lack of freezing winters, at least in the lowlands where the plants are preserved. The trees, whether tree ferns, seed ferns, cordaites, or the great scale trees, bore succulent foliage of almost unprecedented luxuriance. Not merely were the leaves large, but their texture indicates rapid growth under warm, humid conditions. For example, the very large size of the individual cells, the arrangement of the stomata (breathing pores), the smoothness and thickness of the bark, the presence of aerial roots, and the absence of growth rings in the woody trunks are all features of significance. One of the foremost paleobotanists of our times concluded that "the climate of the principal coal-forming intervals of the Pennsylvanian was mild, probably nearly tropical or subtropical, generally humid, and equable."[1]

The animal life of the time also seems to support this view. Insects, for example, attained an extraordinary size and, so far as known, averaged larger than in any other period of Earth history. Since it is well known that the modern orders of insects have their large representatives in the tropics, with smaller and smaller species in regions of more rigorous climate, the significance of the Pennsylvanian insects is obvious. To this may be added the fact that at certain times during the period corals were able to thrive in great abundance and to form reefs as far north as the arctic islands of Spitzbergen (lat. 78° N.). The presence of these ancient reefs in the sea cliffs of a land now treeless and ice-covered speaks eloquently of the climatic contrast between

the present and the Pennsylvanian age in this region (Fig 164) The exceptional abundance of the large fusulines in the limestones of the northern hemisphere, and even as far north as Spitzbergen, seems to have a significance like that of the insects

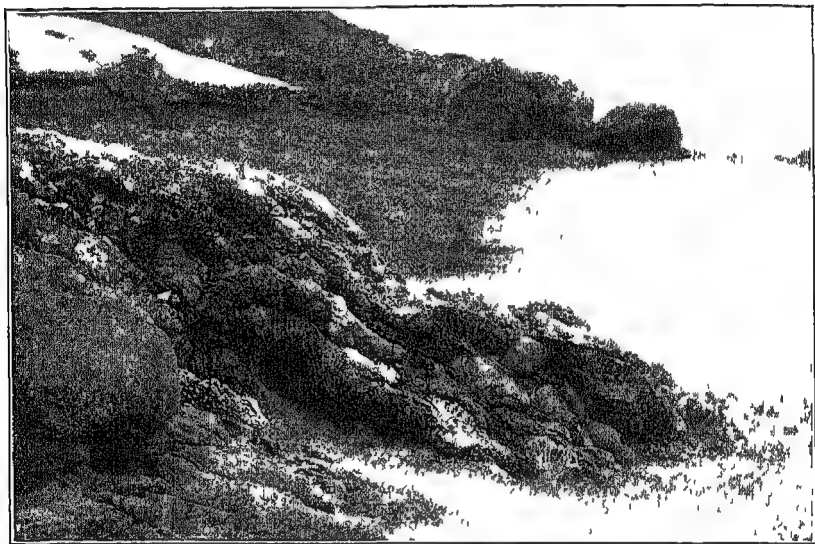
Nevertheless, we must not assume that all parts of the world were warm Great changes have occurred in the temperature of most of the

O Holtedahl

Fig 164 Coral reef in the Early Pennsylvanian (Moscovian) deposits of western Spitzbergen Both tetracorals (*Campophyllum*) and tabulates (*Chætetes*) contribute to the deposit The present arctic climate is indicated by the snowbank at the left

lands in the few tens of thousands of years since the Pleistocene ice age During a period like the Pennsylvanian, of millions of years' duration, there may have been important fluctuations in the world climate

The extensive continental glaciation of India, South Africa, South America, and Australia, which some geologists attribute to Late Pennsylvanian time, we regard as of Permian age It is discussed in Chapter 13

Without a doubt the polar regions were cooler than those of low latitudes, and it may well be that the mild climate of Spitzbergen was due to the local influence of a warm ocean current which then streamed into the Arctic Nevertheless, the evidence for mild climate is so

widespread that we can not avoid the belief that in general the Pennsylvanian was an exceptional period in the climatic history of the Earth.

## Life of the Pennsylvanian Period

### *Forests of the Swamp Lands*

Forests of fast-growing, soft-tissued trees, tangled in dense undergrowth, spread over the moist lowlands of the Pennsylvanian landscape. Among these were none of the deciduous forms like those of our modern forests, for they had not yet evolved. The giants of the time were strange, spore-bearing trees which today are represented only by insignificant, herbaceous descendants like the ground pines and scouring rushes (Fig. 165).

Under the moist and perpetual summer of the coal swamps, shades of green must have been dominant. It is likely that the monotonous verdure was rarely enlivened by bright colors, for the primitive flowers of the time were simple and doubtless small as a rule. There was probably no honey to lure the insects and no sweet perfumes to scent the air, only fresh resinous odors such as pervade the living conifer forests.

Although seed-bearing plants were common, spore-bearing trees were even more abundant and at certain seasons must have covered the forests with a greenish yellow or brownish dust of spores, since some of the coals (cannel coal) are composed almost entirely of spore cases.

*Ferns* of many kinds were common, and they alone gave a modern aspect to the dells of these ancient forests. The leaves of some species attained huge proportions, single fronds reaching a length of 5 or 6 feet, and the slender, unbranched trunks grew to be as high as 50 feet.

*Seed ferns* resembled the true ferns in every respect save one: they bore small nutlike seeds instead of spores appended to their fronds. They may have descended from ferns and in turn may have given rise to all the higher, seed-bearing plants. They were more common than the true ferns in Pennsylvanian time and have often been confused with them, since the two groups can be distinguished only when fruiting fronds are found.

*Scouring rushes* of giant size grew in solid stands like "cane brakes" in portions of the swamps. Like their humbler modern descendant, *Equisetum*, they are easily recognized by their vertically ribbed and regularly jointed stems (Figs. 165, 166). The Paleozoic forms bore

*Fig. 165. A Pennsylvanian landscape showing characteristic animals and plants. Part of a great mural by Rudolph Zallinger. Plants: 1, a tree fern, 2, Lepidodendron, a scale tree, 3, Sigillaria, a scale tree, 4, Cordaites, a precursor of the conifers, 5, Calamites, a giant scouring rush. Animals: 6, Diplovertebron, 7, Eryops, 8, Eogyrinus, 9, Seymouria, 10, Limnoscelis, 11, Meganeuron, a giant dragonfly. Numbers 6–8 are amphibians, numbers 9–10 are reptiles.*

at each joint a whorl of slender simple leaves which in modern rushes are represented only by bractlike vestiges. The leaf whorls, known as *Annularia*, commonly present a false resemblance to flowers. The largest of the Pennsylvanian rushes belonged to the genus *Calamites*. Some of these exceeded 12 inches in diameter and had a height of 30 or more feet. Their trunks were not solid woody stems but rather thin woody cylinders filled with a core of pith and surrounded by thick bark, the woody layer seldom having a thickness of 2 inches.

The *scale trees* were the most imposing plants of the forests and in many places the most common. Their name is derived from the fact that their close-set leaves left permanent leaf scars over the trunk and

limbs that make them appear scaled (Figs 166, 167) So striking is this deception that twigs have been mistaken by amateur fossil hunters for petrified snake skins. The scale trees grew to a large size, their stumps reaching a diameter of 4 to 6 feet and then slowly tapering trunks an extreme height of more than 100 feet Most of them belonged to one of two well-defined types, *Lepidodendron* or *Sigillaria*

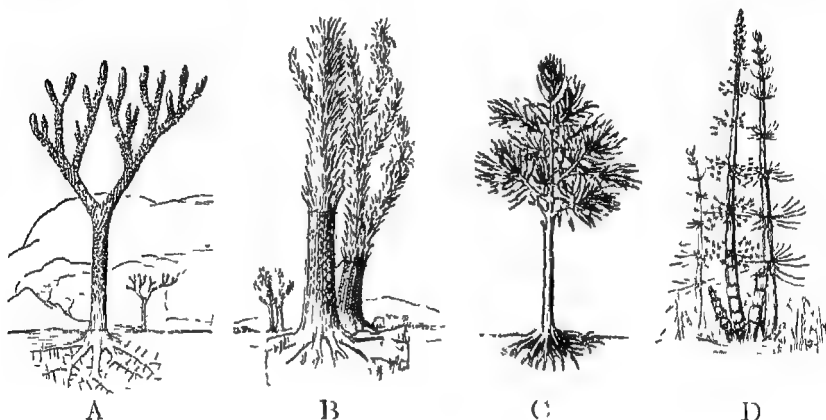



Fig 166 Coal Measures plants A, *Lepidodendron*, B, *Sigillaria*, C, *Cordaites*, D, *Calamites*

*Lepidodendron* (Figs 165, 166) grew a tall slender trunk branching repeatedly near the top to present a spreading crown of stubby twigs covered with slender straplike leaves These leaves, like immensely overgrown pine needles, in some species were 6 to 8 inches long and ½ inch wide The older leaves were shed as new ones formed at the tips of the branches, leaving sharply defined diamond-shaped leaf scars which were normally arranged in spiral rows about the limbs and the trunk (Fig 167) The branching was normally dichotomous (with equal forks) Spore cases were borne as cones at the tips of the limbs

*Sigillaria* (Figs 165, 166) possessed a thicker trunk which rarely branched and was clothed for several feet from the top with large bladelike leaves, resembling those of *Lepidodendron* but larger. In these trees the bark was vertically ribbed, and the leaf scars were normally in vertical rows Trunks have been found with a diameter, just above the roots, of 6 feet, and one specimen is known to be 100 feet long without a branch

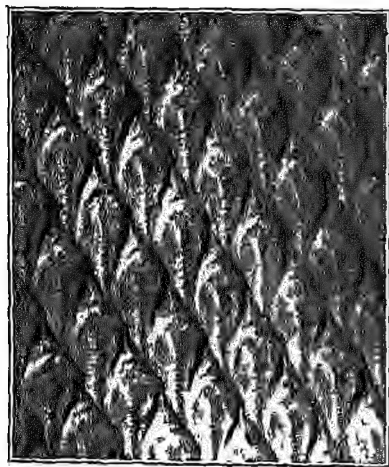
About 100 species each of *Sigillaria* and *Lepidodendron* have been described Although many of them were large trees, some were relatively small In all of them the structure of the trunk and limbs was peculiar in that they had a relatively large center of pith surrounded by a woody cylinder, and this in turn by two very thick layers of corklike bark The leaf scars are impressed only on the bark The root system likewise was peculiar, the main trunk roots spreading almost horizontally without a tap root, moreover, they branched but a few times and so were stubby and thick The real rootlets sprang directly from the sides of these trunk roots, radiating thickly away to a distance of several inches Such root stocks, known as *stigmaria*, are common in the fire clays under coal beds and not infrequently appear in the coal

*Yale Peabody Museum*

FIG 167 A bit of the bark of the scale tree, *Lepidodendron nodulatum*, showing the characteristic leaf scars Slightly less than natural size

The *cordaites* (named after the Bohemian botanist Corda) were the forerunners of the modern conifers, which they resembled in their sturdy soft-wood trunks and their parallel-veined leaves (Figs 165, 166) They differed from true conifers in two chief regards (1) their leaves were not needlelike but bladelike, attaining a length of several inches to 5 or 6 feet, and (2) their seeds were borne in racemes instead of being crowded into cones Many of them were tall, graceful trees, some attaining a height of 120 feet and a diameter as great as 3 feet In such trees fully two-thirds of the trunk was without branches, though the top was a dense crown of branches and large simple leaves The wood of the cordaites was much like that of modern pines, but the pith at the center was larger They appear to have been one of the chief contributors to the vegetation that made the Pennsylvanian coal

It is obvious that our knowledge of the Pennsylvanian land plants relates almost wholly to the swampy lowlands Possibly the most rapid advances were being made in the uplands, where the climate was more rigorous and more stimulating but where the chances for preservation of the record were slight

One of the striking features of the Pennsylvanian floras is the marked similarity of the species in different parts of the world. They were as nearly *cosmopolitan* as any in the Earth's history. This must mean that their migration from one continent to another was favored by extensive land connections and by freedom from climatic barriers.

*The Animal Conquest of the Lands*

Through the dank forests of Pennsylvanian time droned clumsy, primitive insects, while centipedes, spiders, and scorpions scurried

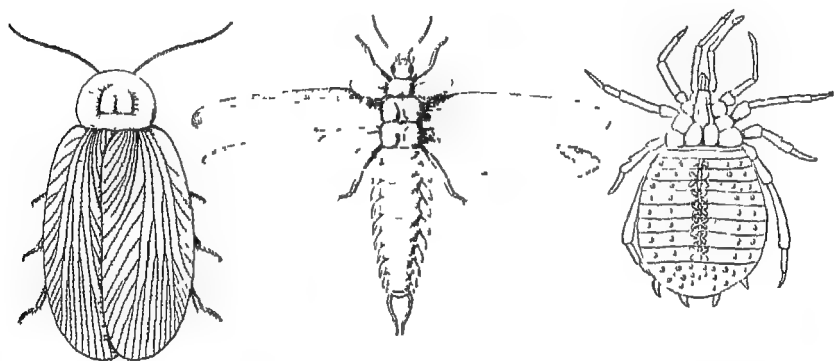



Fig. 168. Pennsylvanian insects and a spider. Left, a cockroach, *Aphthoroblattina johnsoni*; center, a primitive insect, *Stenodictya lobata*; right, a spider, *Eophrynus prestvicii*. Natural size. In part after A. Handlirsch.

about over the fallen logs in search of food. Small land snails worked their tedious way in the trees, and in the swamps a hundred or more kinds of sprawling amphibia lolled about as do crocodiles or giant salamanders (Fig. 165). Before the close of the period the more adventurous of these amphibians had left the water permanently to establish the dynasty of the reptiles. Now for the first time we find the record of varied and abundant land animals; henceforth their dominion over the lands is never for a moment in doubt.

The *insects* of this time were truly remarkable for their great size. Out of four hundred forms known from Lower and Middle Pennsylvanian strata, more than a score exceeded 4 inches in length, six attained to nearly 8 inches, and three exceeded a foot, the average length being about 2 inches. The largest of all was a dragonfly-like type found in the Coal Measures of Belgium, which had a wing spread of 29 inches (Fig. 165). No period since has produced insects so large

Most of these insects were of strange primitive stocks not exactly like any of the modern orders Cockroaches, however, were very like the living ones, only larger, and so common that the period has sometimes been called the *Age of Cockroaches* (Fig 168) Several of the Pennsylvanian species achieved a length of 3 or 4 inches

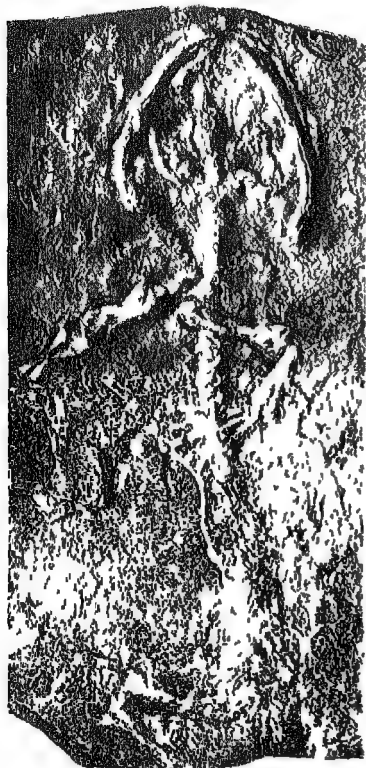



Fig 169 *Pelion lyelli*, a probable ancestor of the modern frogs Specimen imbedded in shale, its back down Lower middle Pennsylvanian shale at Linton, Ohio Natural size Original in the American Museum of Natural History From Roy L Moodie, by courtesy of the U S National Museum

The presence of several hundred species of insects in the Pennsylvanian makes their sudden appearance at this time the more remarkable The diversity of the forms represented implies a long antecedent evolution whose record may yet be found in Mississippian if not in Devonian rocks

*Scorpions*, remarkably like modern ones in size and structure, occur with the insect fossils *Spiders* (Fig 168) likewise occur, though none of the fossils shows clear evidence of spinnerets, and it may be that these early forms did not make webs *Centipedes* (or myriapods) of several kinds are known, the largest of which, found at Mazon Creek, Illinois, had a length of 12 inches

*Land snails* were first discovered in the famous Joggins section of Nova Scotia, where they were associated with the skeletons of amphibia Both had taken refuge in standing hollow stumps that were overwhelmed by floods and buried by sand and mud. Land snails are extremely rare fossils in the Paleozoic rocks, however, and all are small

Small *fresh-water clams* of several kinds (*Carbonicola*, *Anthracomya*, etc ) occur abundantly in the dark shales of certain of the coal fields, especially in Nova Scotia and Europe

*Vertebrate animals* are represented by abundant skeletal remains of *amphibia*. From the Coal Measures of North America alone no fewer

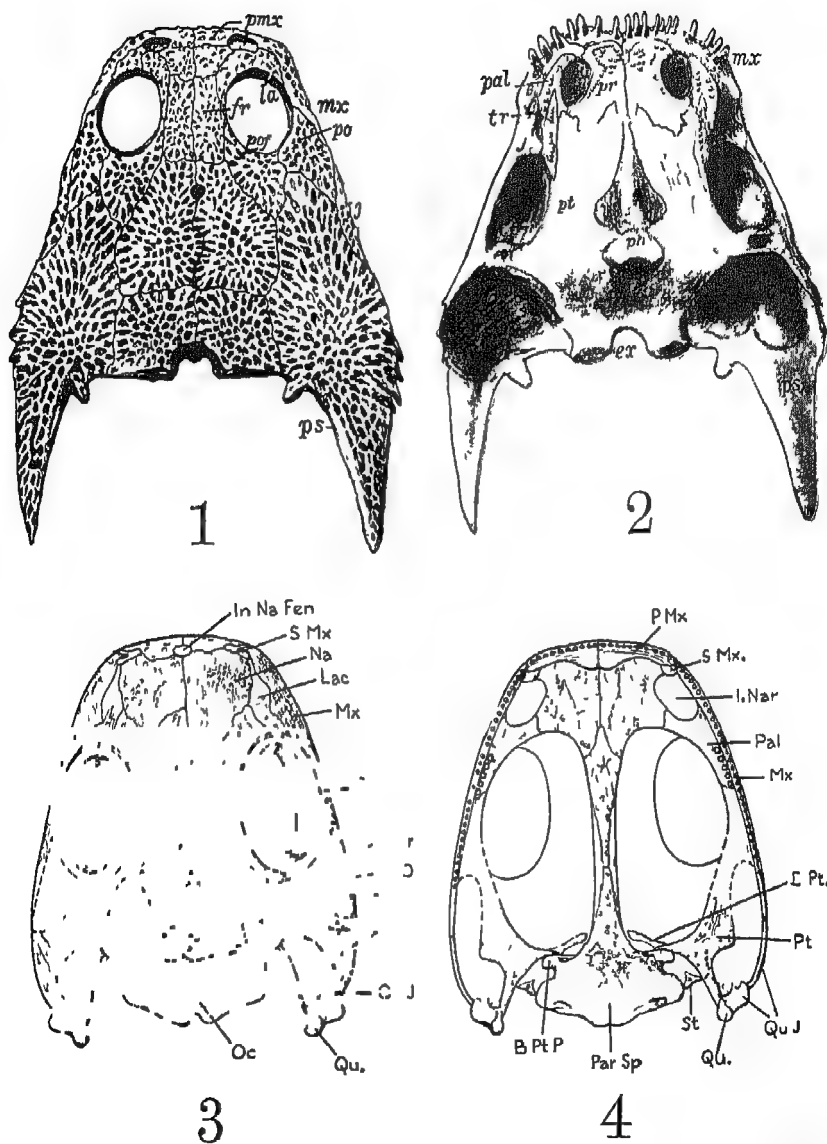



FIG 170 Skulls of Pennsylvanian labyrinthodonts 1, 2, *Diceratosaurus* (dorsal and ventral views) from Linton, Ohio (natural size), 3, 4, *Miobatrachus* (dorsal and ventral views) from Mazon Creek, Illinois (×2¼) After Moodie and Watson, respectively

than 7 orders, 19 families, 46 genera, and 88 species are known Such great diversity suggests that these animals were common in spite of the fact that they are still the rarest of fossils The most remarkable single locality for such remains is at Linton, Ohio, at the base of the Freeport coal, where abundant ganoid fishes and no fewer than 50 species of amphibia have been found (Figs 165, 169, 170)

Fig 171 A primitive salamander (*Eumicrerpeton parvum*), less than 2 inches in length, as reconstructed by Roy L Moodie from specimens found in concretions in the Pennsylvanian shales at Mazon Creek, Illinois

The Pennsylvanian amphibia were labyrinthodonts, and nearly all were small (Fig 171) Many of them were only a few inches long, and large ones, scarcely 10 feet over all, would not exceed a large Florida alligator The greatest of all is known only from its tracks, deeply impressed in Mid-Pennsylvanian sandstone near Lawrence, Kansas This animal (*Onychopus gigas*) had blunt, stubby feet over 5 inches long, and although its stride was only about 30 inches, the right and left treads were wide apart, indicating a short but very heavy-bodied animal estimated to weigh not less than 500 or 600 pounds There is some evidence that the feet were webbed like those of a crocodile

A few *reptiles* of small size appeared during the later half of the period, but their remains are very rare (Fig 172)

### *Résumé of the Marine Animals*

The invertebrate life of the Pennsylvanian seas was not only prolific but also varied Moreover, it was a cosmopolitan assemblage, presenting much the same aspect in various parts of the world

*Brachiopods* (Pl 10, figs 1–6, 8–12) and *lacy bryozoa* continued in great profusion The spiny productids exceeded all other brachiopods and gave a distinctive aspect to all the faunas

The muddy and sandy sea floors seem to have been especially suitable for *pelecypods* (Pl 10, figs 18–22) and *gastropods* (Pl 10, figs 14–17), which were represented by hundreds of species In general, these were still small, however, few of the shells exceeding a length of 1 or 2 inches *Cephalopods* were much less numerous and generally

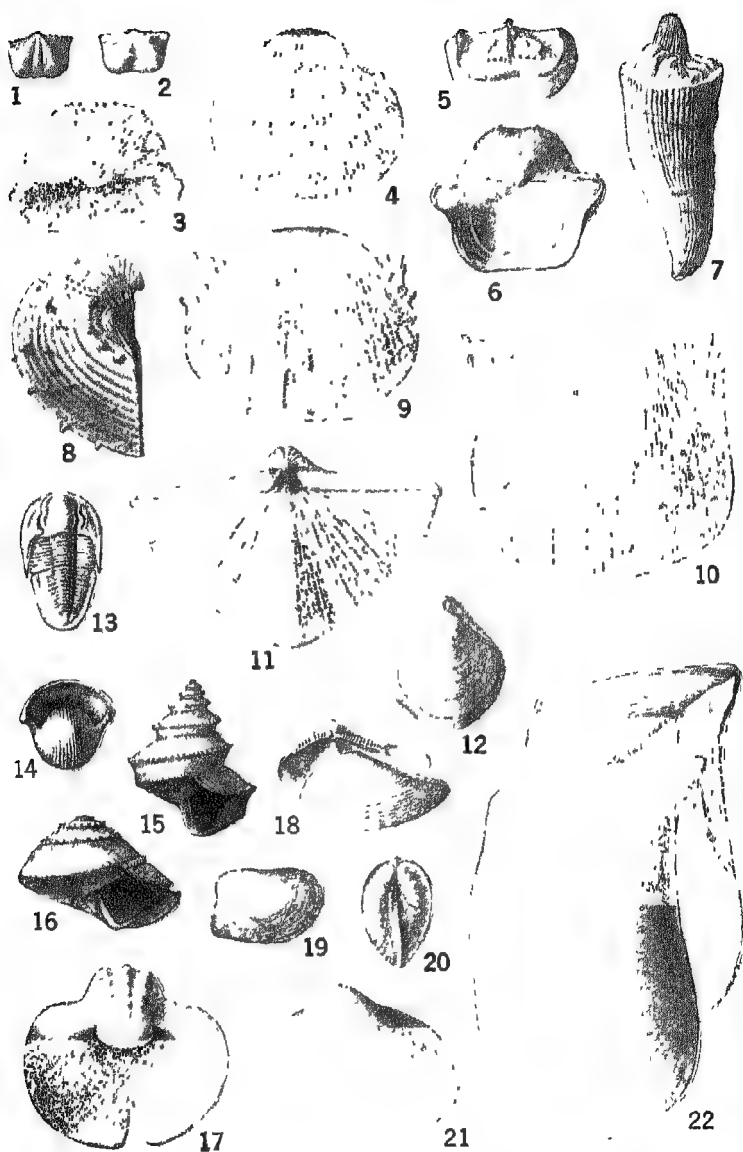



Plate 10 Pennsylvanian Brachiopods (1–6, 8–12), Coral (7), Trilobite (13), and Molluscs (14–22)

Fig 1, *Mesolobus mesolobus*, 2, *Lissochonetes geinitzianus*, 3, 4, *Juresania nebrascensis*, 5, 6, *Marginifera splendens* (5, interior view of dorsal valve), 7, *Lophophyllum profundum*, 8, 9, *Dictyoclostus portlockianus*, 10, *Linoproductus prattenianus*, 11, *Neospirifer dunbari*, 12, *Composita subtilita*, 13, *Phillipsia major*, one of the very last of the trilobites, 14, *Euphemites carbonarius*, 15, *Worthenia tabulata*, 16, *Trepospira sphaerulata*, 17, *Pharkidonotus tricarinatus*, 18, *Nuculana arata*, 19, 20, *Nuculopsis ventricosa*, 21, *Schizodus*

are poorly preserved, though in some regions, especially the coal fields of Europe, they are not so rare and are of great value in stratigraphic correlation Of these, the nautiloids were rather on the decline, but the *goniatites* were rapidly changing into a variety of forms and developing more complicated sutures, foreshadowing the expansion of the typical ammonites during the next period

U S National Museum

FIG 172 The oldest known reptile, *Eosauravus copei* The hind legs and most of the backbone are preserved Lower middle Pennsylvanian beds at Linton, Ohio Natural size From Roy L Moodie, by courtesy of the U S National Museum

*Corals* (Pl 10, fig 7) of a few kinds, mostly solitary types, persisted, but only locally assumed importance Echinodermata are represented by abundant *crinoidal* fragments and the plates and spines of *sea-urchins*, but well-preserved skeletons of either group are not common because the shallow sea floors were wave-swept enough to break apart the echinoderm bodies *Blastoids* made their last stand in the earliest part of the period and are never found above the lowermost Pennsylvanian formations (Wapanucka and Morrow), except in the East Indies, where several genera appear in the Permian

One of the most striking groups of Pennsylvanian fossils is the *fusulines*, a family of relatively large bottom-dwelling Foraminifera They built multichambered limy shells of globular or fusiform shape, whence the name Fusulinidæ, meaning spindle-shaped Commonly they resemble grains of wheat or oats in size and shape They were important rock makers in many parts of the northern hemisphere, where fusuline limestones are widely spread (Fig 173)

Small foraminifers were also common and varied in the Pennsylvanian seas Ostracods were still numerous though nearly all very small

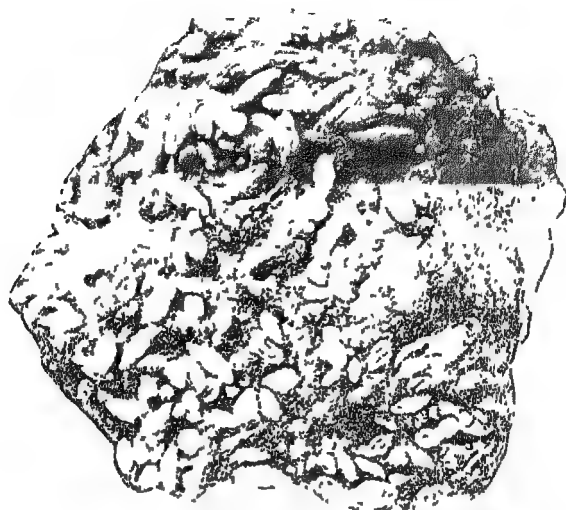
Minute types of fossils, such as foraminifers and ostracods, have proved to be very useful in subsurface correlation in the oil fields,

*Yale Peabody Museum*

*Fig.* 173. Fragment of fusuline limestone from the Upper Pennsylvanian of Kansas. Natural size.

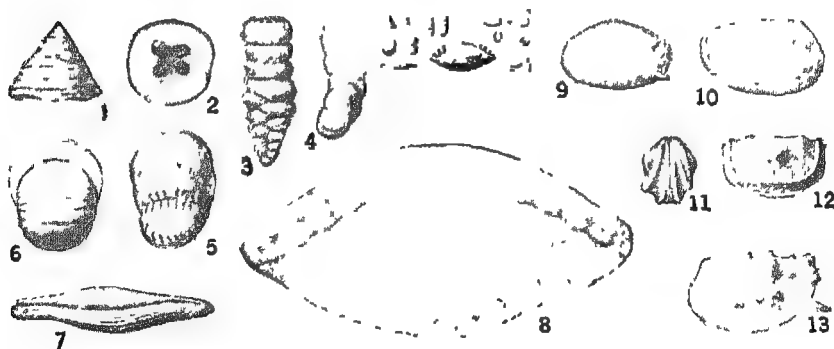



Fig. 174. Microfossils from the Pennsylvanian, greatly enlarged. Foraminifera: 1, 2, *Tetrataxis palaeotrochus* (side and dorsal views); 3, *Climacammina cylindrica*; 4, *Ammobaculites stormi*; 5, *Bradyina magna*; 6, *Staffella keyteri*; 7, *Wedekindellina euthysepta*; 8, *Triticites ventricosus*. Ostracoda: 9, *Healdia limacoidea*; 10, *Glyptopleura menardensis*; 11, 12, *Amphissites centronotus* (end and side view); 13, *Hollinella kellettae*. The insert at center top shows the specimens near natural size.

since they can be recovered from the drill cuttings and, when studied, serve to identify the formation through which the drill is passing. Because of their small size they are commonly spoken of as *micro-*

*fossils* (see Fig 174), and their study has become a specialized science known as micropaleontology

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[2] *Correlation of the Pennsylvanian Formations of North America*, by Raymond C Moore *et al* Bulletin of the Geological Society of America, Vol 55, 1944, pp 657–706

[3] *Bituminous Coal Fields of Pennsylvania*, by George H Ashley Topographic and Geological Survey of Pennsylvania, Bulletin M16, 1928, p 99

[4] *The Origin of Coal*, by D White and R Thiessen U S Bureau of Mines, Bulletin 38, 1913, pp 67–75

## Collateral Reading

*The Coal Fields of the United States*, by M R Campbell 33 pages U S Geological Survey, Professional Paper 100-A, 1917

*Paleobotany A Sketch of the Origin and Evolution of Floras*, by E W Berry Smithsonian Institution, Annual Report for 1918–1920, pp 289–407

Includes a somewhat technical but readable account of the late Paleozoic plants

*The Coal Measures Amphibia of North America*, by Roy L Moodie 222 pages Carnegie Institution of Washington, Publication 238, 1916

A technical but well-illustrated review of the vertebrate life of this period

## CHAPTER 13

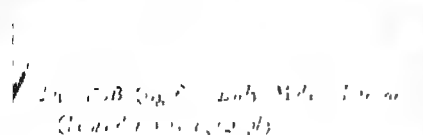
# THE PERMIAN PERIOD, A CRISIS IN EARTH HISTORY

Momentous changes ushered the Paleozoic era to its close As the mobile borderlands continued to rise and were thrust against the emerging continents, several of the great Paleozoic geosynclines were uplifted into fold mountains These alpine chains stretched along the eastern and southern border of North America, crossed central Europe and southern Asia, and reached southward through the East Indian arc The Urals also were formed at this time As the enlarged continents interfered with the ocean currents, so these far-flung chains of lofty mountains disarranged the atmospheric circulation, and gave rise to climatic extremes of unprecedented severity

The widespread glaciation and the long-continued aridity which swept over large parts of a world previously adjusted to warm, moist climates caused organic changes of the most drastic sort Land animals, and land plants as well, struggling against a new and harsh environment, either made effective adaptations or became extinct Judged by the changes that occurred, the Permian must be reckoned as one of the great crises in the history of life

**Founding of the Permian System.** Almost as soon as the early Paleozoic systems were defined, Murchison and Sedgwick were concerned to know whether they would be recognizable in other regions Travel in Germany, the Alps, and Belgium confirmed their hopes that they would In all these regions, however, the rocks are much disturbed, hence, when rumors were brought back that Paleozoic strata were flat-lying over great areas in Russia, Murchison determined to extend his exploration in that direction The publication of his great classic, *Siluria,* had brought him such renown that it was easily arranged for his expedition to proceed under the royal patronage of the Czar He was joined in this undertaking by two friends, the Russian geologist, Count Keyserling, and his French colleague, De Verneuil.

In western England and Wales, where so many of the systems had been named, the Coal Measures are succeeded by redbeds that are in the main unfossiliferous In Russia, however, Murchison found the Coal Measures overlain by a widely distributed series of highly fossil-

iferous rocks, partly terrestrial but largely marine. These he first studied in the province of Perm on the western flank of the Urals, and from these exposures he called them the *Permian system*. Later work has shown that the system can be recognized in many other regions and that the older part of the redbeds overlying the Coal Measures of England and Germany is of the same age, though deposited under different conditions. The extensive development of Permian rocks in America was not recognized until after 1900, when the thick and richly fossiliferous sections of west Texas and New Mexico were discovered, but it is now clear that we have a Permian section unexcelled in any part of the world.

## Physical History of a Changing World

**Final Emergence of the Appalachian Geosyncline.** Over eastern North America the change from Pennsylvanian to Permian conditions was transitional rather than abrupt. A mountainous borderland stretched from Newfoundland to Mexico, and the region of the Appalachian geosyncline remained a broad alluvial plain crossed by sediment-laden streams flowing westward toward the retreating sea. Deposition continued for a time across the central part of the geosyncline, as shown by the *Dunkard group* in southeastern Ohio and northwestern West Virginia (Fig. 175*A*). Probably these formations were originally more extensive along the trough and were largely destroyed by erosion later in the period.

Before Middle Permian time the uplift had become general over the whole of the eastern United States, so that the streams carried their burdens through to the basin which then occupied the Mid-Continent region, and deposition ceased over the Appalachian trough, which later in the period was folded into an anticlinorium and destroyed forever as a geosyncline. Thus with the close of the Paleozoic era came an end to one of the grandest features of ancient North America. Since earliest Cambrian time the Appalachian trough had subsided intermittently during every period, and had been the site of the most persistent interior seaways, trapping some 50,000 feet of strata. With the Permian came a change so profound that the region has never since been crossed by the sea!

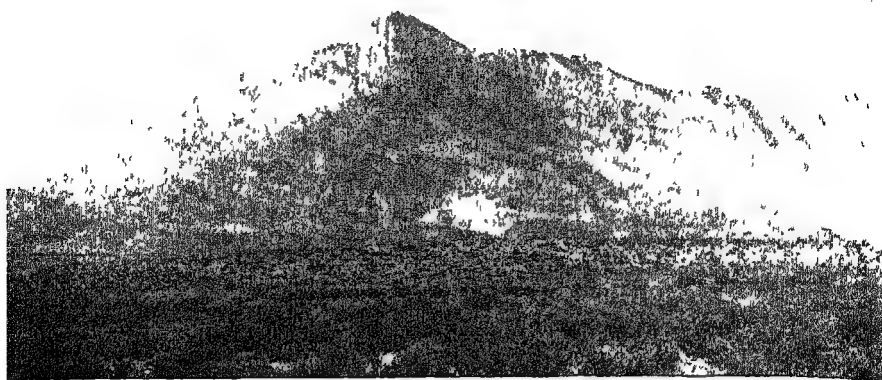
The Dunkard group of Ohio and West Virginia is almost wholly nonmarine, including plant and insect fossils and a few thin coal beds. One thin zone has yielded, in addition, the brachiopod *Lingula* and a few shark spines, indicating that for a very brief time the sea reached

CARL O DUNBAR

*Fig 176 Guadalupe Mountains viewed from the south The light-colored summit of the range is made of the Capitan reef-limestone, which in El Capitan Point (center) forms sheer cliffs over 1300 feet high The slope below the limestone is formed of the Delaware Mountain sandstone which has a thickness of about 3000 feet*

this far eastward Otherwise no marine Permian is known east of Kansas

**Vanishing of the Mid-Continent Seaway.** The Mid-Continent region, from Kansas and Nebraska southward across Texas, remained a vast basin of deposition, as it had been in the previous period, and here, too, the change from Pennsylvanian to Permian conditions was transitional, though ultimately profound (Fig 175)

Early in the period a shallow sea reached northward to southeastern Nebraska and eastern Kansas In the extensive area of outcrops across Texas, Oklahoma, and Kansas, early Permian formations consist of alternating shales and thin limestones generally similar to those below As we ascend in the section, however, evidence of a gradual and profound change is seen In successive marine horizons the fossils are reduced to fewer and fewer kinds, as corals and echinoderms drop out and finally bryozoans and brachiopods also disappear Above some hundreds of feet of such beds lies a thick gray shale (Wellington shale) bearing the great salt deposits of Kansas It is succeeded in turn by red sandstones and maroon shales without fossils

From this record we may infer the following history At the beginning of the period an extensive epeiric sea occupied the region of the western Great Plains It doubtless spread far east of the present outcrops and at one time reached temporarily to Ohio Its outlet to the south across Oklahoma was restricted by the growth of a great delta from Llanoria, which surrounded the Arbuckle and Wichita mountains

as the modern delta of the Hwang-Ho surrounds the Shantung peninsula in China Deltas were also growing eastward from the Colorado Mountains in New Mexico The climate gradually became so arid that evaporation exceeded precipitation, and eventually a vast dead sea occupied the middle of the basin which centered over Kansas and Oklahoma One group after another of the marine animals died out, and eventually the water became a brine from which salt was precipitated Across Mexico and the Gulf a connection with the ocean was maintained through which more salt water was supplied as evaporation proceeded Eventually the waters disappeared, either because the basin was filled to sealevel, or because of regional warping Then, streams converging into the basin spread over its desert floor hundreds of feet of red mud and sands For a time, extensive sand dunes covered parts of Oklahoma, where they are preserved in the Whitehorse sandstone In the redbeds there are occasional zones of gypsum, which seem to indicate a temporary return of seawater and partial evaporation, though not enough to precipitate salt

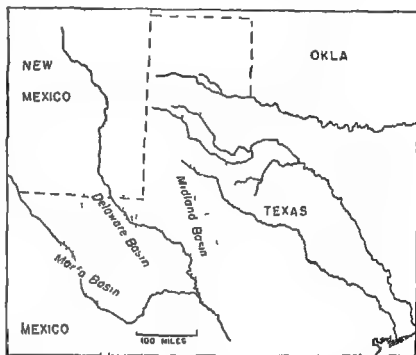



FIG 177 Sketch map showing the extent of the Guadalupe basin (*sparse stippling*) and of its deeper subdivisions (*dense stippling*) After Philip B King

The *Kansas dead sea* marks the last stand of the Paleozoic epeiric seas east of the Cordilleran region Even this sea had vanished before the close of the period, and we must turn to the far Southwest for a record of Late Permian time

**Guadalupe Basin of West Texas and New Mexico.** The grandest Permian record in America, if not in the world, occurs in western Texas and southeastern New Mexico, where Permian strata total about 14,000 feet in thickness This was a basin, occupied much of the time by a seaway which entered through Mexico, and toward which the drainage converged from the Eastern Interior Out of the midst of it now rise the Guadalupe Mountains with a superb display of Permian rocks (Fig 176), and for these the entire depression of Permian date may be called the *Guadalupe basin* (Fig 177) Within this major depression there were three subsidiary and rapidly sinking areas, the *Delaware basin* in Trans-Pecos Texas and southeastern New

Mexico, the *Marfa basin* farther southwest, and the *Midland basin* of central-western Texas (Fig. 177).

As the rest of the Mid-Continent region emerged into lowland and the climate turned increasingly arid, local conditions in the Guadalupe basin gave rise to exceptional Permian deposition. Evaporation was matched by a steady flow of the marine water from the basin to its bordering shallow fringe. This caused deposition of limestone along the margins of the basins where the water was warmed and began to be concentrated. The result was the growth of reeflike limy banks between the deeper basins and vast marginal lagoons (Fig. 178). The

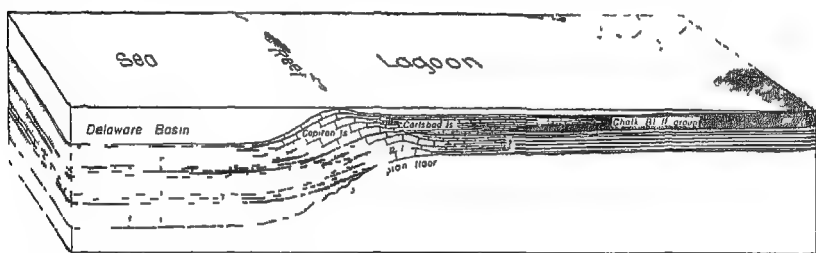



FIG. 178. Block diagram showing relations as they existed about the northern margin of the Delaware basin near the close of Middle Permian time. Front side of the block shows a section through the Capitan reef with deeper water in the basin at the left and shallow water in the lagoon behind the reef. Low delta plains appear at the extreme right. Length of the section along the front face about 12 miles, vertical scale exaggerated.

latter tended to become salt pans in which the red muds from the surrounding lands settled, to intertongue with deposits of gypsum and anhydrite and salt; while nearly pure limestone was accumulating over the reefy areas, and dark shales, dark limestone, and siltstone were deposited in the deeper water of the basins. In the lagoons, life was sparse or limited in variety, the reefs were inhabited by numerous highly specialized brachiopods and by other invertebrates which preferred this environment, and the sea floors of the basin included a varied and more normal population. Thus, in this region the Permian strata of any given time commonly present three distinct facies—one of lagoonal deposits (slabby limestone, gypsum, salt, and redbeds), one of massive reefy limestone, and another of normal marine strata—each grading locally into the other with astonishing abruptness (Fig. 178).

Finally, during the last epoch of the period, the marine water shrank into the deeper part of the basin to form a dead sea (Fig. 179), in which phenomenal deposits of salt and anhydrite were precipitated. These are discussed on page 292.

**Changes in the Cordilleran Region.** In the Far West, also, important changes were taking place During early Permian time a southwestern embayment included eastern Nevada and much of Utah, and a new seaway ran northwestward across California Thick and nearly pure limestones of this age in southern Nevada and in northern California imply that the near-by lands were still low During the middle part of the period, however, volcanoes were active in California, western Nevada and Idaho, and eastern Oregon (Fig 175*C*) This was apparently the first outbreak, and the forerunner of the great igneous activity that was to characterize the Pacific border during Mesozoic time Near the middle of the period a new trough occupied the central part of British Columbia, extending southward into Washington and Oregon and bearing an oriental fauna not known farther south in America

Fig 179 Paleogeography of North America during latest Permian time (Ochoa epoch)

Permian rocks are also widely distributed in arctic America, notably along the west coast of Alaska, along the Yukon River, and in Cape Lisburne on the arctic coast of Alaska, also along the northern border of Sverdrup and Parry Island groups and in Ellesmere Island These outcrops bear fossils indicating a common connection across the northern margin of the continent from Alaska to East Greenland and thence, via Spitzbergen and Novaya Zemlya, with the Ural region of the USSR

## Far-Reaching Orogeny and Continental Uplift

**The Appalachian Revolution.** During or at the close of this period Appalachia was thrust westward against the geosyncline, folding and thrusting the thick Paleozoic formations into a great mountain chain that extended unbroken from Newfoundland to Alabama Practically all the structures now visible in the ridge and valley province

south of New England date from this disturbance. In New England and Maritime Canada the earlier disturbances (Taconian, Acadian, etc.) had more or less strongly deformed the rocks of the geosyncline, and there the effects of these several movements are compounded and difficult to separate, but south of New England the great mountain folds (Fig. 180) date entirely from the Appalachian revolution.

The movement was clearly later than the Early Permian, since the Dunkard group is gently deformed along with the older strata, and it was long before the middle of the Triassic, since the folds had been locally peneplaned before deposition of the Triassic Newark group began. In the absence of late Permian and early Triassic formations

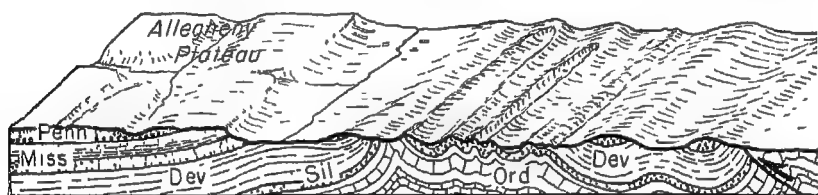



Fig. 180. Section across Appalachian structures in central Virginia, from the edge of edge of the Martic thrust appears at the extreme right, and two other thrusts are shown horizontal.

the movement can not be more precisely dated, though it probably culminated at the end of the Permian period.

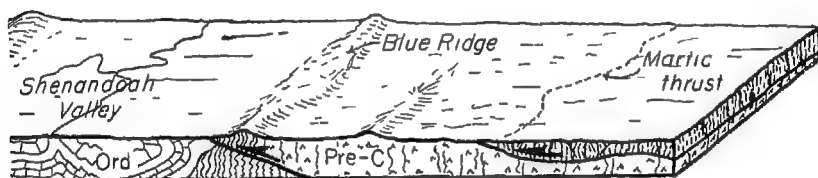
A cross-section of the Appalachian province (Fig. 180) shows clearly that the moving force was from the southeast. For example, along the eastern margin of the geosyncline a series of thrusts of great magnitude carried Cambrian and younger rocks westward until in places they rested upon the Coal Measures. Figure 181 shows the position of the greatest of these faults. The Martic thrust can be traced from Georgia to Pennsylvania, a distance of more than 500 miles, and the Blue Ridge fault extends over 700 miles, from Alabama into Pennsylvania. Westward movement of as much as 12 miles has been recorded on a single thrust.

In the belt of thrust faults the softer rocks are strongly crumpled (Fig. 182), and the folds are generally overturned to the northwest. The intensity of deformation dies out to the westward, however, and the folds are more and more open until the beds lie nearly horizontal in the Allegheny Plateau. The effect of the folding and faulting has been to reduce greatly the original width of the folded belt. It has been estimated that the section between Philadelphia and Altoona, Pennsylvania, was shortened by 100 miles,[1] and that the entire geo-

syncline, with an original width of 500 miles, is now reduced to 270 miles

It is impossible to determine how high the mountains stood at any given time during the Permian, but they probably rivaled the modern Alps in grandeur The amplitude of some of the folds in Pennsylvania (Fig 183) would suggest a height of 5 miles, but this is probably too great, since the highest peaks must have suffered rapid erosion as they slowly rose, moreover, we do not know how much regional uplift went along with the folding

Much igneous action accompanied the movement in the mobile zone Extensive granites in the modern piedmont belt (Fig 181) and prob-

the Allegheny Plateau (left) to the Piedmont slope near Richmond (right) The western to the left of it Length of section about 100 miles, vertical scale about 2½ times the

ably part of the granites of New England were intruded at this time Profound erosion has since removed such volcanics as may have existed, and laid bare these deep-seated intrusives This removal of the younger rocks from the intruded masses has made it difficult to date the granites with assurance, but the fact that their minerals do not show strain or shearing proves that the intrusion did not precede the Permian thrusting

**The Ouachita Disturbance** The structures of the Ouachita Mountains of Arkansas and Oklahoma (Fig 179) appear also to have been formed in the Permian They present a northward-facing arc of intensely folded Paleozoic formations, lying in a series of great imbricated thrust sheets The whole mass of the mountains has been thrust northwestward, probably tens of miles, over the eastern end of the older Arbuckle range There is still some uncertainty as to the exact time of the thrusting It involves thick Lower Pennsylvanian formations and is, of course, younger than these Moreover, the Ouachita thrusts override the Arbuckle Mountain structures, which in turn were uplifted during Pennsylvanian time It appears probable, therefore, that the Ouachita structures were formed by Permian thrusting [2]

**Volcanoes of the Pacific Border.** In California the middle Permian (Nosoni) formation includes much volcanic tuff and lava Recently a very characteristic Permian shark (*Helicoprion*) was found in west-central Nevada in tuffaceous shale interbedded in volcanics that exceed 13,000 feet in thickness It is uncertain whether all the igneous material is Permian, but the middle part, at least, is so Also in eastern Oregon and west-central Idaho volcanics (Castro formation) thousands of feet thick include a few thin marine beds bearing Permian fossils These facts indicate the presence of an extensive field of volcanoes during the middle part of Permian time in eastern California, western Nevada, and along the Idaho-Oregon boundary There was likewise much volcanic activity in central Mexico and Alaska in Permian time This extensive outburst in the Permian was only the forerunner of the great igneous activity of the Mesozoic era

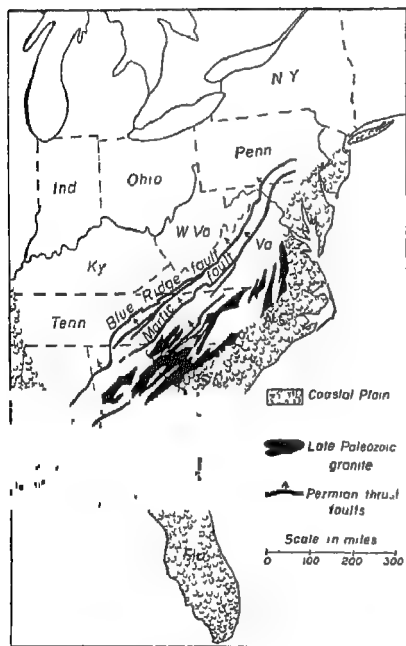



FIG 181 Sketch map showing distribution of late Paleozoic batholiths (*solid black*) and the traces of major thrust faults (*heavy lines*) in the southern Appalachians Overlapping deposits of the Coastal Plain are shaded Adapted from Anna I Jonas

**Permian Mountains of Eurasia.** Crustal instability seems to have been as great in Europe as it was in North America during Pennsylvanian and Permian time The Urals, which closely parallel the Appalachians in structure as in history, were folded during the Permian, while the Variscan chains were completed across southern England, Germany, and northern France

## STRATIGRAPHY OF THE PERMIAN SYSTEM

**Guadalupe Basin.** In the Guadalupe basin, where the Permian strata reach a thickness of 14,000 feet, they have been subdivided as follows

4 Ochoa series
3 Guadalupe series
2 Leonard series
1 Wolfcamp series

The *Wolfcamp series*, 500 to 700 feet thick, is entirely marine in this area and consists of interbedded limestone and shale In the Glass Mountains, where it rests unconformably on the Marathon folds, it includes basal deposits of coarse limestone breccia It is characterized by distinctive fossils of which the large ventricose foraminifer, *Pseudoschwagerina*, is most diagnostic From numerous outcrops in extreme western Texas it dips eastward under younger rocks and reappears in north-central Texas (Fig 175*A*) There it consists largely of shale but includes numerous persistent limestones and is divided into many formations and members (upper Cisco and Wichita groups) Traced

G W STOSE, U S GEOLOGICAL SURVEY

*Fig 182 Folds in thin-bedded Silurian rocks, produced by the Appalachian revolution The surface visible here is due to erosion and is not the original surface resulting from the folding "Fluted rocks" on Great Cacapon River, West Virginia*

northward toward the Arbuckle Mountains, the limestones disappear and the entire series goes over into conglomeratic redbeds, still farther north, however, limestones reappear, and in Kansas and southern Nebraska, where these rocks have been called the Big Blue series, they are marine and richly fossiliferous The change of character about the Oklahoma Mountains is due to the locally derived sediment and perhaps to the growth of a large delta deposited by streams draining the Eastern Interior

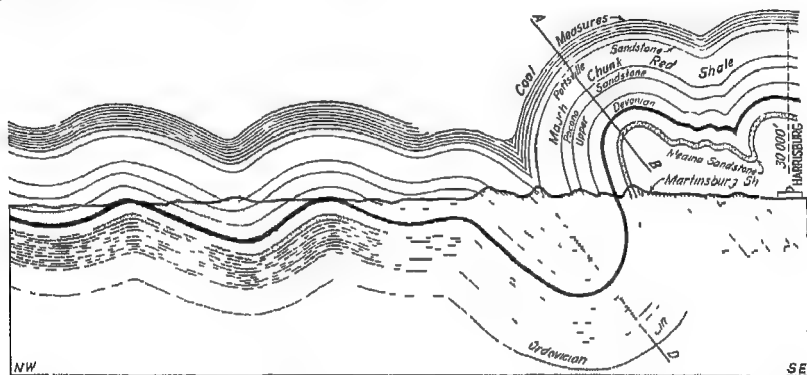



FIG 183 Reconstruction of the eroded folds near Harrisburg, Pennsylvania, showing the size of the original folds Length of section about 15 miles, vertical scale not exaggerated *AB*, axial plane of an overturned anticline, *CD*, axial plane of an overturned syncline Adapted from a diagram by George Ashley, Topographic and Geologic Survey of Pennsylvania

The *Leonard series*, more than 2000 feet thick in the Guadalupe basin, varies locally from gray shale to nearly black shale to black limestone and to pure white limestone, but is wholly marine in this area Dipping eastward under cover, it reappears in central Texas, in the form of redbeds with but few thin limestones and much interbedded gypsum From here northward across Oklahoma and Kansas it is chiefly a redbed series Fossil reptiles have been found in the red shales in Oklahoma, and both reptiles and labyrinthodonts (Fig 193) in north-central Texas These land animals were obviously living along the sluggish streams that wandered over a vast alluvial plain Marine fossils are limited to a few very thin zones in Texas and Oklahoma, and apparently most of the redbeds are fluvial deposits At the top of the series, however, there is a very widespread zone of gypsum (the Blaine formation) extending continuously from Kansas into Texas It was apparently formed in vast lagoons largely cut off from the sea which still occupied the Guadalupe basin, and the pre-

cipitation of so much calcium sulphate implies severe aridity and excessive evaporation over the whole Mid-Continent region

The *Guadalupe series* is most fully developed in the Delaware basin, where it is completely marine and shows with exceptional clarity the changes of facies discussed on p 284 These are illustrated in Fig 178 Around the margins of the basin, shallow banks of reeflike nature grew nearly to sealevel, forming a bar between the deeper water of the basin and the shallow lagoons that stretched away to the north and east The Delaware Mountain group, formed in the basin, consists largely of sandstone and siltstone interbedded with numerous dark sandy limestone beds It is still a problem how such a vast quantity of sand got through the lagoons and past the reefs into the depth of the basin, probably it was swept in through breaches in the reefs where streams entered from the Eastern Interior

The reef limestone is peculiarly massive and now stands out in bold cliffs in the Guadalupe Mountains (Fig 176) As the reefs rose some hundreds of feet above the floor of the basin and tended to grow basinward, the Capitan reef limestone here appears to overlie the Delaware Mountain sandstone, but in places along the flank of the range, beds of the dark limestone in the upper part of the Delaware Mountain group rise to intertongue with the white limestone, defining the original slope of the reef front Back of the Capitan reef lie the lagoonal deposits, including bedded limestone near the reef, grading out into variegated shales and including precipitates such as gypsum and anhydrite Over a vast area in central Texas, Oklahoma, and Kansas, red muds and sands accumulated to form the Whitehorse group, which may be largely nonmarine, but several thin beds of fossiliferous dolomite among the red shales in central Texas indicate temporary incursions of the sea over this low alluvial plain At one time the marine waters reached to central Oklahoma, but in northern Oklahoma and southern Kansas part of the Whitehorse sandstone is cross-bedded in such fashion as to indicate dunes

Meanwhile, dark marine shales and volcanics were accumulating in central and northern California, and thick deposits of volcanic material formed in eastern Oregon and western Idaho In central Mexico (Las Delicias area) the marine Permian of this date likewise includes much volcanic material

In British Columbia, on the contrary, the Permian formations (Cache Creek group) contain thick and rather pure limestones

The *Ochoa series* (Fig 184) reaches a thickness of 4450 feet in the Delaware basin and includes one of the world's greatest deposits of

salt During the closing stages of the Permian the deeper parts of the Guadalupe basin formed a dead sea in the midst of a vast desert lowland (Fig 179) Limited connection with the ocean via Mexico allowed an inflow of water to replace evaporation until saturation was reached and salt and anhydrite were precipitated For a time the deposition was confined to the Delaware basin, and there the Castile deposits, as much as 2000 feet thick, consist almost wholly of chemical precipitates, chiefly banded anhydrite ($CaSO_4$) and halite (NaCl)

By the time this deposition was completed, the Delaware basin was largely filled, and deposition spread more widely over the Guadalupe

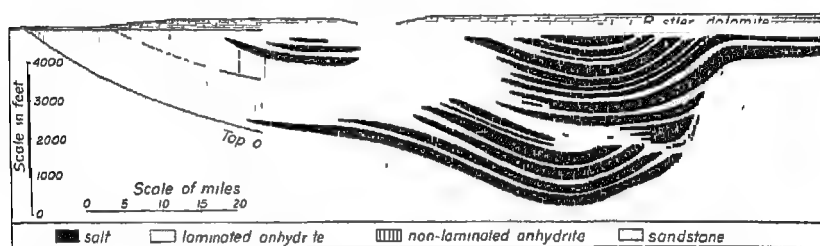



FIG 184 Cross-section of the Delaware basin as it existed at the close of Permian time, showing the stratigraphic relations of the Ochoa series Adapted from George A Kroenlein

basin Concentration continued meanwhile, and the Salado formation accumulated to a maximum thickness of 2400 feet Over much of the basin this formation is made up of rock salt or halite interbedded with anhydrite and including near its middle one of the greatest known deposits of potassium salts Toward the margins of the basin the chemical precipitates grade laterally into variegated shales

Following the chief salt deposition there were laid down the Rustler formation of dolomite and variegated shales, and, finally, the Dewey Lake redbeds of nonmarine origin

The lamination so common in the Castile gypsum is well shown in Fig 185 The light layers are nearly pure anhydrite, and the thin, dark layers have considerable organic matter and microscopic crystals of calcite The well from which this core was taken passed through more than 1200 feet of such laminated material Udden gave reasons to suspect that these are seasonal precipitates, the purer layers representing the drier season and the darker layers a more humid season On this assumption, and from a count of the laminæ in this well core, Udden estimated that it required 306,000 years to deposit the Castile and Salado formations

The total evaporation implied by so much salt is colossal King has recently estimated that, if the salt were precipitated from normal seawater which constantly flowed into the basin to replenish the loss, an average evaporation of about 9½ feet per year over the 10,000 square miles of the basin would be required for a period of 300,000 years[7] Since the average evaporation in Death Valley is only about 11½ feet, this is a striking commentary on the Late Permian climate of this region

**Cordilleran Region** As indicated in Fig 175, the southern part of the Cordilleran trough was occupied by a shallow sea during much of Permian time This left an imposing marine record in southern and eastern Nevada, most of Utah, southeastern Idaho, and extreme western Wyoming Farther east, redbeds accumulated over a great area surrounding the Colorado Mountains

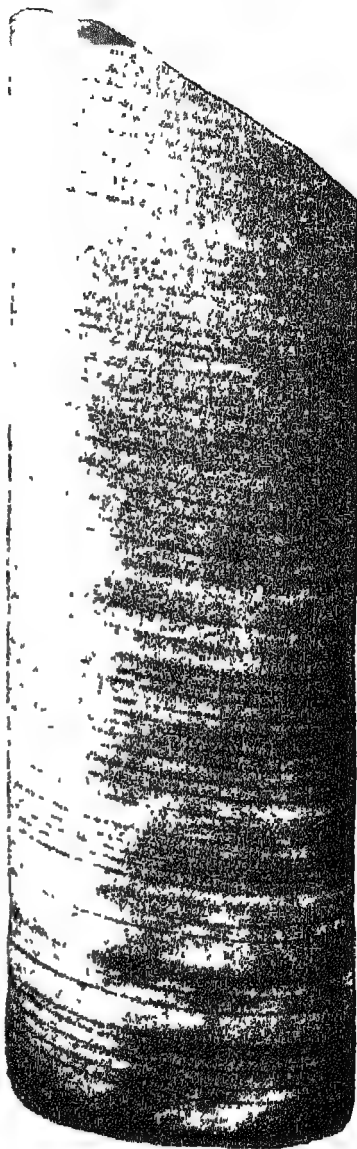
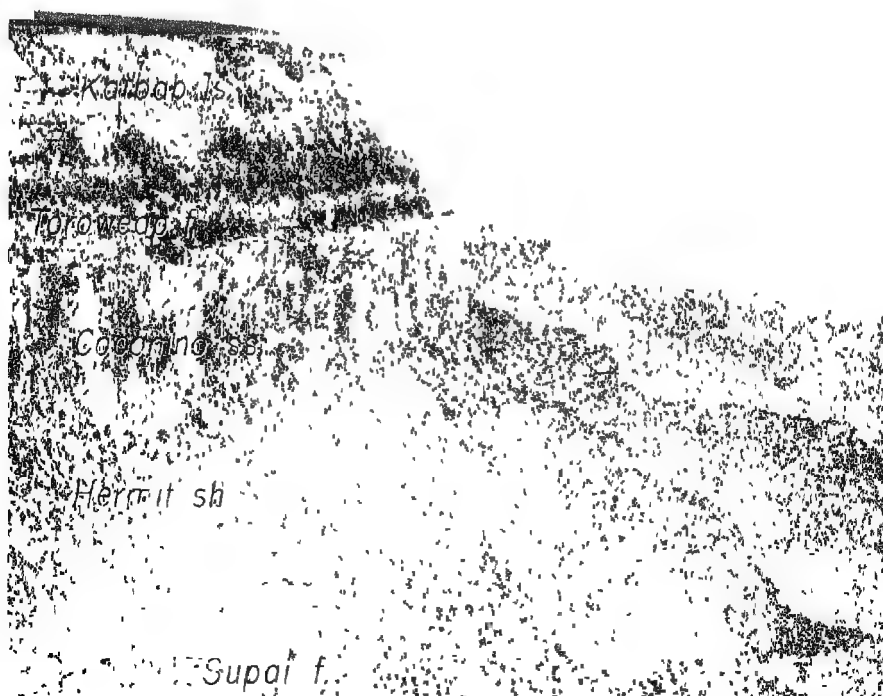
Grand exposures of these Permian formations of the Far West are to be seen in the walls of the Grand Canyon (Fig 186), where the lateral change of facies from redbeds to marine sediments may be studied The general relations are suggested by Fig 187 The Kaibab limestone is a key horizon rimming the inner gorge of the canyon in unscalable cliffs from 500 to 600 feet in height It persists as a marine horizon from southern Nevada to northeast Utah, but in southeast and east-central Utah grades laterally into sandstone like the Coconino The Toroweap formation (until recently

*Yale Peabody Museum*

FIG 185 Piece of a deep well core (natural size), showing the laminated anhydrite ($CaSO_4$) of the Castile formation From Gresham Well No 1 in Culbertson County, Texas This is the well core on which Dr Udden's study was based

included in the Kaibab) consists of a marine limestone with redbed members both above and below it The limestone thickens and largely replaces the redbeds in southern Nevada, but thins toward the east and is replaced first by redbeds and then by the massive, cliff-forming, light gray Coconino sandstone

In the familiar Bass Trail section, in the eastern part of the Grand Canyon, the Coconino sandstone rests on soft red Hermit shale, and that in turn on the Supai formation of red sandstone, siltstone, and shale (Fig 187) The Supai rests disconformably on the Redwall limestone of Mississippian age Traced westward, the Hermit shale becomes sandy and takes on the character of the Supai formation

CHARLES SCHUCHERT

*Fig 186 Looking northwest from Yaki Point along the south wall of the Grand Canyon Here the Permian formations total slightly over 2600 feet in thickness and rest disconformably on the Redwall (Mississippian) limestone*

At the same time the typical Supai redbeds become calcareous toward the west and grade over into the upper part of a great mass of marine limestone, which has been called the Callville formation just west of the Grand Canyon and the Bird Springs limestone still farther west. In southern Nevada that great mass of limestone, exceeding 5000 feet in thickness, includes in its lower part both Pennsylvanian and Mississippian deposits, while the upper part is Permian. The pre-Permian

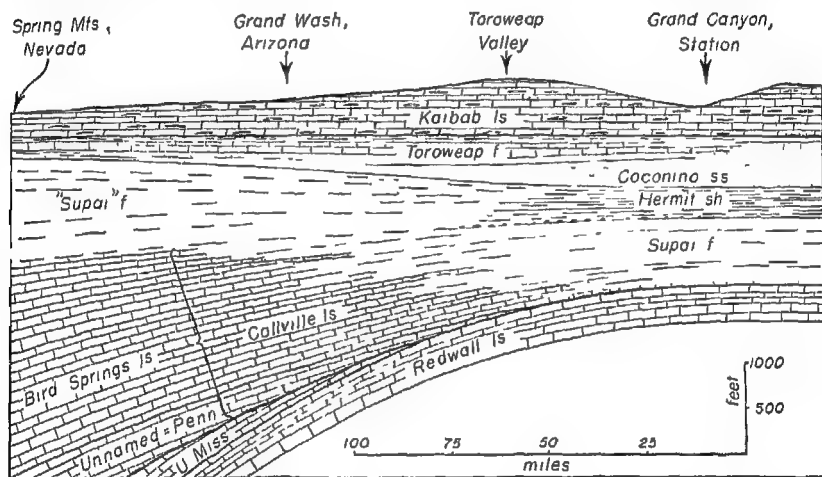



FIG 187 Idealized section of the Permian formations between southern Nevada and north-central Arizona, showing the westward thickening and change of facies. The right end represents the well-known sequence at the east end of the Grand Canyon. Data from Edwin D. McKee (personal communication)

beds overlap out against the underlying Redwall limestone near the western end of the Grand Canyon, and the Permian part alone grades eastward into the Supai redbeds (Figs. 5, 187).

Throughout this province marine limestone, fluvial redbeds, and wind-blown sands were deposited simultaneously according to local conditions, and, as these conditions shifted geographically during the period, complex changes of facies occurred.

A great area of Mesozoic rocks separates the exposures of the Grand Canyon region from those of northern Utah and southeastern Idaho, where the Phosphoria formation is the most widely distributed and best-known Permian deposit. Where typically developed, it includes a basal member of black phosphatic shale and a thicker, upper member of cherty limestone, but toward the northeast it intertongues with, and is finally replaced by, red shales (lower part of the Chugwater

formation) that extend across Wyoming and into the rim of the Black Hills of South Dakota Its marine fossils indicate that the Phosphoria formation is younger than the Kaibab Its absence from the Grand Canyon region may be due to post-Permian erosion The Phosphoria formation rests on Pennsylvanian or older beds in Wyoming, but in Idaho and northern Utah it is underlain by sandstones of great thickness (Oquirrh and Wells formations), the upper portion of which probably represents, at least in part, the Permian formations of the Grand Canyon section

## Climate

It was but a natural sequel to these and other great changes in the physical geography that climatic extremes were introduced The extensive withdrawal of all the epeiric seas during Permian time removed one of the chief agents in stabilizing the temperature and providing moisture to the winds that crossed the interiors of the continents The enlarged lands must have interfered greatly with the spread of warm ocean currents toward the poles, particularly in the southern hemisphere, where a land bridge (Gondwana) (p 307) is believed to have crossed the Atlantic At the same time each lofty mountain range which stood athwart a prevailing wind belt must have increased precipitation on the windward side and reduced it on the lee The extensive highlands were chilled by their altitude Under these conditions local extremes of climate are not the paradoxical but the natural thing

**Deserts.** During the Permian period, deserts were probably more widespread than at any other time save the present The dune sands and the widespread deposits of salt and gypsum in the central and western United States indicate a vast interior more arid than the present Great Basin The salt beds that stretch from Kansas to New Mexico have been estimated to include 30,000 billion tons of salt and would require the evaporation of more than 22,000 cubic miles of sea-water with a salinity like that of the modern oceans. This precipitation, it must be remembered, occurred while only a part of the Permian formations were forming The salt is not all of one age, in Kansas it is in early Permian strata, and in west Texas the chief deposits are in the latest Permian formations

Central and western Europe were also strongly arid during a part of Permian time In Soviet Russia the Uralian geosyncline was then a great trough lying just west of the modern Ural Mountains For a

time shortly before the middle of the period it included a dead sea in the midst of a vast desert basin in which the Kungurian series formed In the deepest part of this basin, about Solikamsk, these deposits exceed 4500 feet in thickness, are largely formed of salt and anhydrite, and include probably the world's largest accumulation of potash salts

The Stassfurt region of Germany has another of the great deposits of salt, one which until recently has been the world's chief producer

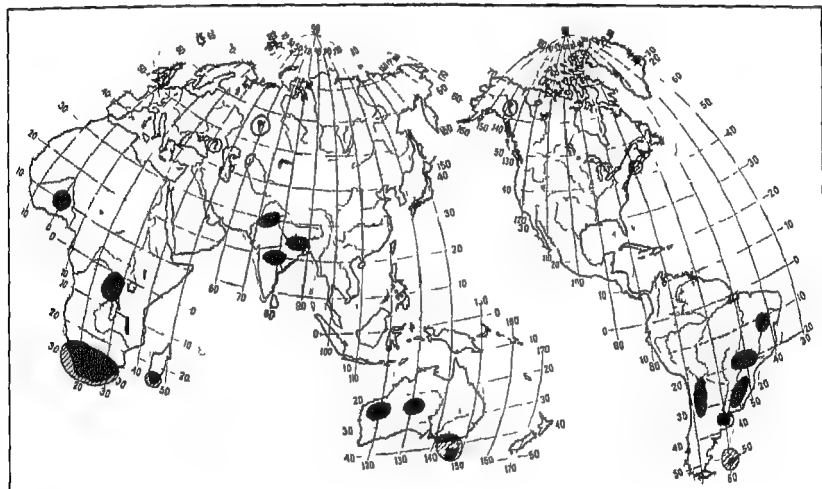



Fig 188 Distribution of Permian glaciation (*black*) Base map by courtesy of the American Museum of Natural History

of potassium Thus three areas—one in southwestern United States, one in the U S S R , and one in Germany—include the world's three greatest salt deposits, and all are of Permian date

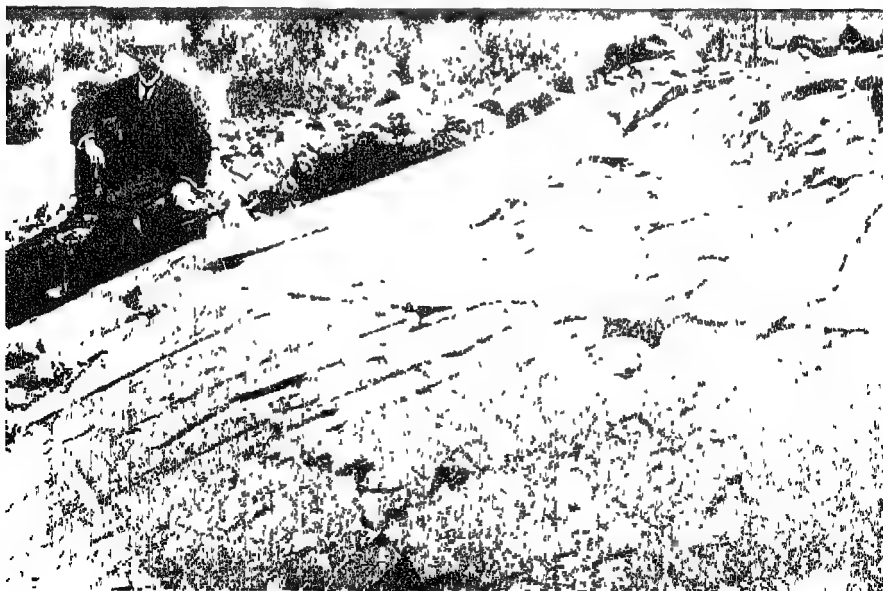
In South Africa the Permian deposits are largely nonmarine redbeds, though there they are not associated with salts or dune sand, and, on the contrary, include a wonderful assemblage of fossil reptiles

Although aridity seems to have prevailed over much of the United States and central Europe, there was abundant rainfall in some regions, notably north China and eastern Australia, where important coal fields lie in the Permian rocks

**The Permian Ice Age** At times during the Permian period great areas in the southern continents were covered with ice sheets (Fig 188) South Africa has the most spectacular evidence of glaciation, for there the ancient Dwyka tillite at the base of the Permian sequence includes large faceted boulders and rests upon the heavily scored and

polished floor over which the ice moved (Fig 189) The ice cap covered practically all of southern Africa up to at least latitude 22° S and also spread to Madagascar (which was then part of the continent) There were three or four centers of movement, but the greatest seems to have been in the Transvaal, which then was a plateau from which the ice moved southwestward for a distance of at least 700 miles The tillite reaches a thickness of less than 100 feet in the northeast but increases to 2000 feet in southern Karroo Australia was likewise the scene of extensive and repeated glaciations, the ice apparently moving northward across Tasmania, Victoria, and New South Wales A series of five sheets of tillite is interbedded in some 2000 feet of Permian strata which have at least one horizon of commercial coal South America bears evidence of glaciation in Argentina and southeastern Brazil, even within 10° of the equator In the northern hemisphere, peninsular India, within 20° of the equator, was the chief scene of glaciation, with the ice flowing north, in the Salt Range on the southern flank of the Himalayas the thick Talchir tillite underlies the marine Permian

A P COLEMAN

*Fig 189 Glaciated floor beneath the Dwyka tillite near Kimberly, South Africa*

In the northern land masses other than India, on the other hand, evidences of glaciation are very restricted The only certain evidence in North America is a small deposit near Boston, the Squantum tillite, which may be the result of a valley glacier from the rising Appalachians Striated boulders in conglomerates have been found in the Permian beds in different places in Alaska, but the proof of their glacial origin is not conclusive The same may be said of doubtful occurrences in England, Germany, south Russia, and central Africa

It is almost certain that the Permian ice age, like the recent one of Pleistocene time, was a relatively brief episode in a long geologic period The three widely spaced repetitions of glacial beds in the thick Australian sequence may indicate recurring glaciation in that continent In any event, the main glacial deposits are in each region confined to a limited horizon of the older Permian rocks The presence of large reptiles in the higher Permian redbeds of South Africa and of northern Russia would suggest a mild-temperate climate without freezing winters at the time when they lived

The exact *time of the ice age* is difficult to prove in any of the glaciated regions Possibly it was not the same in all the continents, though it would seem more probable that such extensive refrigeration must have affected the temperature of the whole world at once It now appears that the best-dated glaciation occurred before the middle of the period, but long after the beginning of Permian time

The most remarkable feature of the Permian glaciation is its *distribution* It was chiefly in the southern land masses and in regions which now lie within 20° to 35° of the equator This circumstance, more than any other, has made attractive the belief in "continental drift" If the southern continents were united to Antarctica until after Permian time, the glaciation may not have spread into low latitudes A later "drift" of these continents toward the north would account, far more easily than any other means yet postulated, for the present distribution of the glacial deposits But this premise itself is still in the realm of speculation[1]

## Permian Life

**Decline of the Carboniferous Floras** In the northern hemisphere the dominant types of Pennsylvanian plants lived on into Permian time Lepidodendrons, sigillarias, calamites, cordaites, and seed ferns were the common forest types during the early part of the period These swamp-dwelling plants were ill adapted to the oncoming aridity

*Fig 190 A Permian landscape showing characteristic animals and plants Part of a great mural by Rudolph Zallinger Plants 1, Cordaites, 2, Araucarioxylon, a conifer, 3, Lepidodendron, a scale tree, 4, Walchia, a conifer Animals 5, Varanosaurus, a reptile, 6, Eryops, an amphibian, 7, Edaphosaurus, 8, Dimetrodon, 9, Sphenacodon, 10, Araeoscelis Numbers 7 to 10 are "fin-backs"*

and to winter cold With the passing of the period, therefore, hardier stocks with reduced foliage evolved, or came to the fore, as the Pennsylvanian types declined (Fig 190) By the close of the period the great scale trees were almost extinct The cordaites were likewise nearly gone, having first given rise to the conifers Seed ferns were rare after the close of the period, and the race died out in the Jurassic

*True conifers* rapidly sprang into the lead as the dominant type of woody trees, while primitive cycadeoids (allies of the sago palm) foreshadowed the expansion of higher plants in the Mesozoic

**The *Glossopteris* Flora of the Glaciated Regions** Throughout the southern hemisphere and in India, the Permian floras are charac-

terized by the small, hardy, thick-leaved "tongue ferns," *Glossopteris* and *Gangamopteris* These had simple, tongue-shaped leaves borne on creeping stolons or rootstalks (Fig 191) They bore seeds, and were not ferns but relatives of the cycads Although they have been regarded as a response to the harsh climate of the glaciated regions, it has been commonly supposed that they did not actually live under frigid conditions but entered the glaciated regions during interglacial or postglacial ages [1] Recent discovery of *Glossopteris* spores in the tillite in both India and Australia, however, indicates that *Glossopteris* actually lived under glacial conditions [2]

Fig 191 Leaf of the Permian "tongue fern," *Glossopteris indica* From Credner's *Elemente der Geologie*

By Middle Permian time some members of the flora had migrated as far as northern Russia and the Altai Mountains of Siberia, but none ever reached western Europe or North America Along with the *Glossopteris* flora there lived in the southern hemisphere many ferns, conifers, calamites, etc, but none of the great scale trees After the passing of the glacial climates, however, both *Lepidodendron* and *Sigillaria* succeeded in re-establishing themselves to a limited extent during the latter half of the period

**Insects.** Insects (Fig 192) were abundant and extremely varied at this time, though rarely preserved because of their delicate structure However, a small locality near Elmo, Kansas, has yielded many thousands of specimens from a single thin bed in the Lower Permian, and other finds have been made in nearly equivalent beds in Oklahoma, in the Dunkard series in Ohio, in the Lower Permian of Russia, and in the Upper Permian of Australia. All these show great changes from the Pennsylvanian insect types Although a few were still large in the Early Permian, the majority were small and many were minute, showing thereby a striking contrast with the giants of the previous age Moreover, many new orders were now arising, foreshadowing the modern groups Mayflies were common, true dragonflies were present, and in the Late Permian, beetles lived in Australia Cockroaches persisted, but then, as ever afterward, played a minor role in the insect world

**Sprawling Reptiles and Labyrinthodonts** Even in the semiarid regions the old labyrinthodonts clung to the stream courses with sur-

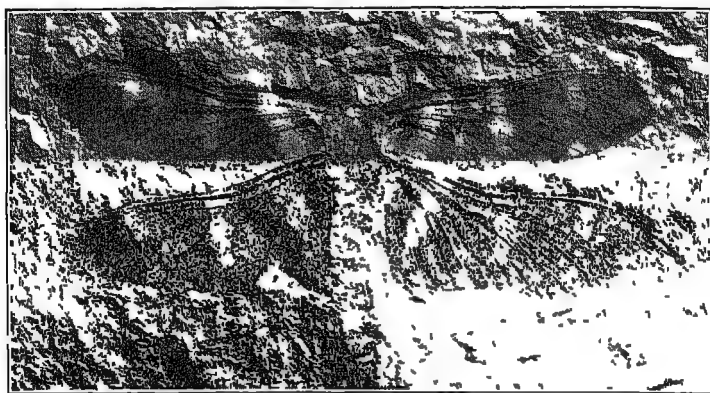
prising success Their heavily armored skulls are locally abundant in old stream-channel deposits in the redbeds of Texas and Oklahoma

*Yale Peabody Museum*

FIG 192 A primitive insect, *Dunbaria fasciipennis*, from the Early Permian beds near Elmo, Kansas, preserving the color pattern of the wings About 2½ times natural size Photograph not retouched

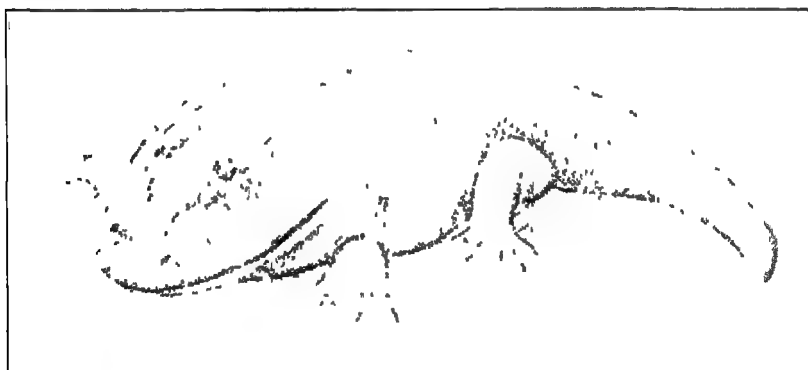
and in the fluvial deposits of Germany and South Africa Nearly all of them had broad heads, thick bodies, and short, feeble legs As Huxley once said, they "pottered with much belly and little leg, like

*Yale Peabody Museum*

FIG 193 A characteristic Permian labyrinthodont, *Eryops megalocephalus* After a model by Dwight Franklin Lower Permian of Texas Length of this species, about 5 feet

Falstaff in his old age" (Fig 193) Probably none exceeded a length of 10 feet

*Reptiles* increased greatly in variety during the Permian The older

forms are known chiefly from the redbeds of Texas and Oklahoma, where conditions of preservation happened to be good, whereas the later kinds come from South Africa, India, northern Russia, and Brazil Before the close of the period they had undoubtedly mastered all the lands, and some even reverted to aquatic life, both in the rivers and in the sea

The great range of specialization which the Permian reptiles display (Fig 194) emphasizes the rapidity of their evolution Most of them

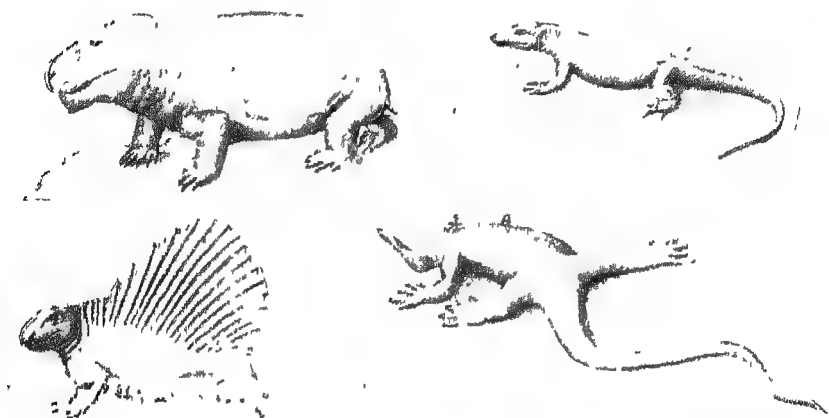



FIG 194 Characteristic Permian reptiles Lower right, *Limnoscelis*, from New Mexico, lower left, *Dimetrodon*, the fin-back lizard, from Texas, upper right, *Varanops*, from Texas, upper left, *Endothiodon*, from South Africa

had long bodies, long tails, and short legs While some were agile and lizard-like (*Varanops*), others were sluggish and semiaquatic like alligators (*Limnoscelis*), and yet others were thick-bodied and had stubby tails and short, thick legs Many had sharp holding teeth and were certainly carnivorous, some had blunt teeth adapted to crushing shelled molluscs or crustaceans, and others, with toothless jaws like those of turtles, may have been herbivorous (*Endothiodon*) They had already deployed into several orders, but none of these corresponds to any of the living groups Two features the Permian reptiles possessed in common (1) none was very large, 8 or 10 feet being a maximum length, (2) all were four-legged creatures and most of them sprawled (Fig 194).

The most bizarre of them all were the "fin-backs," so called because of their greatly extended neural spines The reason for such extraordinary specialization is entirely problematical

Far greater significance attaches to a group of stout-bodied flesh-eating reptiles known as *theriodonts,* which foreshadow the coming of the mammals These are known chiefly from the middle Karroo formation (Upper Permian and Triassic) in South Africa Unlike other reptiles, they had teeth differentiated into incisors, canines, and molars as do the mammals Moreover, they carried their bodies off the ground instead of sprawling Numerous details of skull and jaws confirm their ancestral relation to the mammals, though all of them were still reptiles (Fig 207)

**Specializations and Extinctions among the Marine Invertebrates** The marine invertebrates of the Permian evolved gradually out of the Pennsylvanian faunas As some groups advanced steadily into progressive types, others assumed extravagant specializations which led shortly to their extinction, yet others, already on the decline, gradually died out

The *cephalopods* (Pl 11, figs 5–9) showed the most significant gains, as goniatites with more and more complex sutures gave rise to typical ammonites The rapid evolution of this group foreshadowed their spectacular rise to dominance among the marine invertebrates of the next era

"The Permian was the Golden Age for the ammonids Almost all the genera were branching out in various directions and almost anything (in the way of evolution) was possible for them There is no forewarning, as yet, of the many tragedies of extinction, reversion, and degeneration that cloud the later history of this prolific group

Thus the forebears of all the stately and beautiful genera of the Triassic may be seen in the simple and unpretentious forms of the Permian "

Pelecypods and gastropods progressed steadily but more conservatively Among the *brachiopods* (Pl 12), which generally make up the bulk of the faunas, the productids remained the dominant group, while several new genera, growing fast to the bottom, developed into most extraordinary types, and some of them even grew conical shells mimicking corals (Pl 12, fig 11) Before the close of the period, however, all the productids and most of the other groups of brachiopods died out The *fusulines* (Pl 11, figs 1–4) continued as important rock makers and attained their maximum size near the close of the period, though none survived the end of it The trilobites, already nearly extinct, died out, as did all the honeycomb corals and the tetracorals, likewise most of the groups of crinoids, all the blastoids, and two of the orders of bryozoa

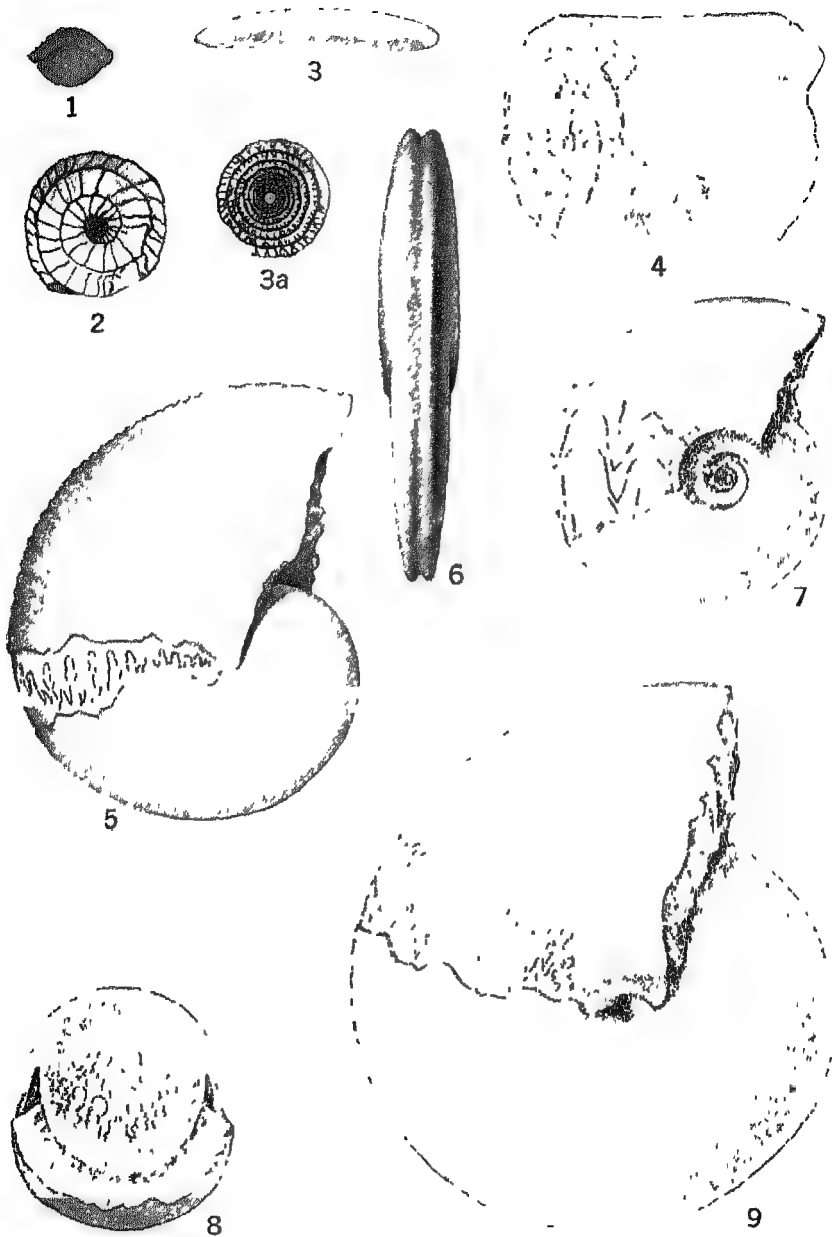



Plate 11 Permian Fusulinids (1–4), and Ammonites (5–9)

Fig 1, *Pseudoschwagerina uddeni*, 2, enlarged section of same, 3, *Parafusulina wordensis*, 3a, enlarged section of same, 4, model of portion of a shell showing septa, 5, 6, *Medlicottia whitneyi* (lateral and edge views), 7, *Gastrioceras roadense*, 8, *Waagenoceras dieneri*, 9, *Perrinites vidriensis* All natural size except 2 and 4 Drawn by L S. Douglass

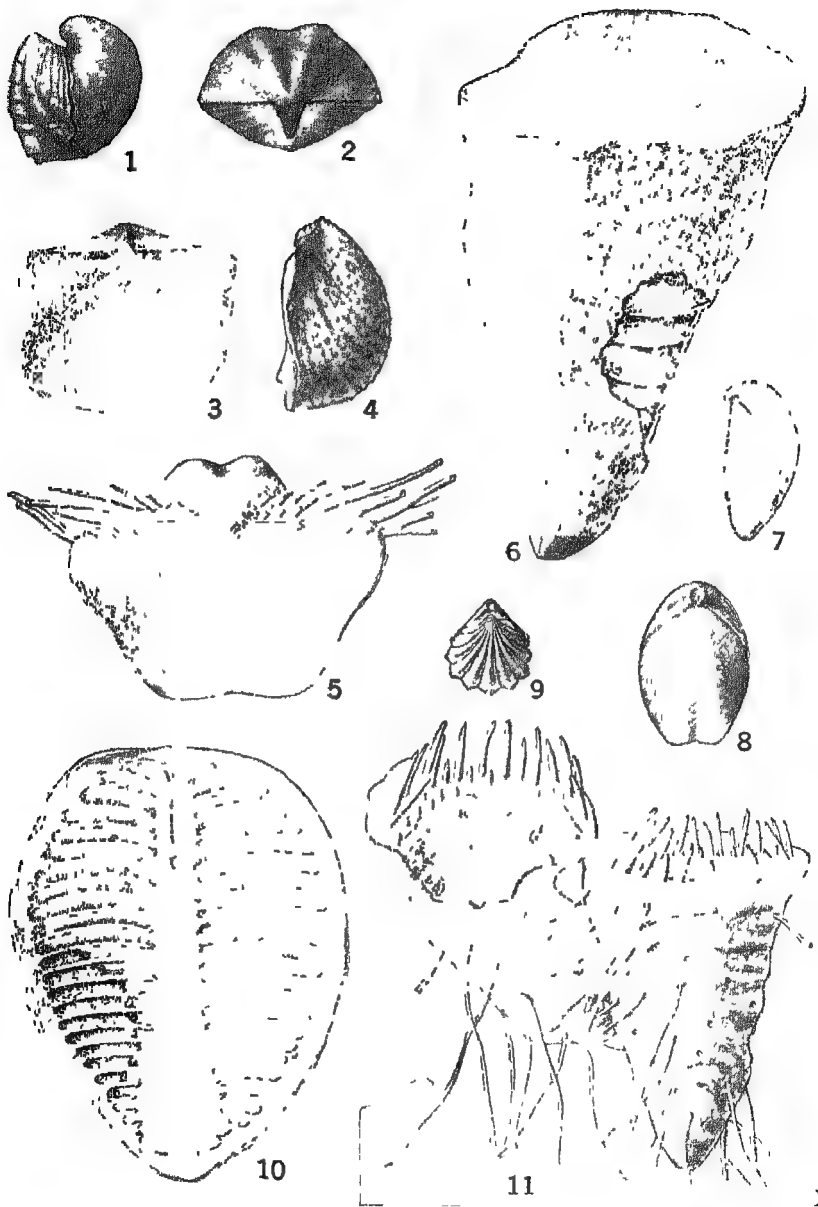



Plate 12 Permian Brachiopods

Figs 1, 2, *Parenteletes latesinuatus*, 3, 4, *Aulosteges medlicottianus*, 5, *Horridonia horrida*, 6, *Scacchinella gigantea* (with break in conical ventral valve showing internal septa), 7, 8, *Dielasma angulatum*, 9, *Hustedia meekana*, 10, *Leptodus americanus* (showing skeletonized dorsal valve and corresponding flanges in spoon-shaped ventral valve), 11, *Prorichthofenia permiana* (two specimens in position of growth, that at the left broken at the front margin to show the operculiform dorsal valve on its seat below the overarching spines, the dorsal valve also broken) All natural size Drawn by L. S. Douglass

Partly because of the great differences between the Late Paleozoic and Triassic life of the seas, and partly because in many regions (Germany and Russia especially) the Permian rocks have limited faunas, the misconception has arisen that the Permian was a time of great organic restriction and that the oceans may then have contained relatively few kinds of life Such is, however, far from the truth More species are now known from Permian than from Pennsylvanian rocks The rich marine Permian faunas of the East Indies, especially on the island of Timor, contain not less than 600 species in 285 genera, and in the Salt Range (Punjab) of India there are 325 forms. Southwestern Texas has in its Permian rocks probably more than 500 species

This was a time of rapid evolution, great specialization, and constant change The net result was the disappearance of many of the characteristic groups of the Paleozoic life, but the change was orderly and gradual, not cataclysmic

## Gondwana Land Bridges

The living animals and plants of the island of Madagascar show so many resemblances to those of Africa that a former land connection is generally recognized Similar faunal and floral evidence in some of the Paleozoic and Mesozoic formations of India, Africa, South America, and Antarctica strongly indicates that these lands also have been connected A striking instance is the *Glossopteris* flora, which is characteristic of the Permian of the southern hemisphere and occurs with little change in each of the land masses mentioned above Since these plants are entirely unknown in North America, they could have reached both Africa and South America only by some southern route To explain such facts some geologists have invoked the theory of continental drift, believing that the continents were originally together and have since migrated apart, but most geologists now think it more probable that the continents have remained fixed, the former connections having been narrow land bridges such as that which now unites North and South America [7]

On the assumption (now discredited) that South America, Africa, and peninsular India were once broadly connected to form a great transverse continent, this hypothetical land mass was called *Gondwanaland* Those who believed in such a land assumed that the continents were eventually separated by a breakdown of the areas which now form the southern Atlantic and Indian oceans This, however, involves the serious difficulty of explaining how such vast areas of

the crust could have increased in density until they settled to the level of ocean basins—a difficulty that is greatly lessened if we assume the connections to have been merely slender isthmuses or island arcs

Land bridges between the southern continents appear to have existed from early Paleozoic time till the middle of the Mesozoic, and then to have begun to break down

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*Isthmian Links*, by Bailey Willis Ibid, pp 916–952

## Collateral Reading

*Ice Ages Recent and Ancient*, by A P Coleman 296 pages The Macmillan Co, New York, 1926

Includes an extensive account of the remarkable Permian glaciation

*The Permo-Carboniferous Red Beds of North America and their Vertebrate Fauna*, by E C Case 176 pages Carnegie Institution of Washington, Publication 207, 1915

# *IV. THE MESOZOIC WORLD*

## CHAPTER 14

## THE TRIASSIC PERIOD

**The Mesozoic Era** After the close of the Paleozoic era reptiles came into their own. Dinosaurs soon possessed the lands, while sea monsters splashed and slithered through the waves, and winged dragons took to the skies. Fourteen distinct orders of reptiles then thrived (there are but four in the modern world), and for more than a hundred million years they held undisputed sway, before their dynasty suddenly collapsed.

To the founders of geology who named this the Mesozoic era (Gr *mesos*, middle, + *zoon*, life) this seemed to be the middle of the span of life on the Earth, but we now know that reckoning to be wrong. We have already passed in review far more than half of the history of the Earth and of life.

**The Triassic Period** In Great Britain, where so many of the geologic systems were named, the Coal Measures are overlain by a thick sequence of redbeds. At first these were called the *New Red sandstone*, in contradistinction to the Old Red which lay below the Carboniferous. In Britain they form a lithologic unit, but in Germany a threefold division seemed natural because a gray marine formation (Muschelkalk) is present in the middle, separating the lower redbeds (Bunter) from the overlying nonmarine beds (Keuper and Rhætic). It was for this reason that the German geologist Alberti in 1834 gave the system the name *Trias* (L *triad*, three).

Of course, such a threefold lithologic subdivision is not characteristic of the system generally, and modern usage would call for a geographic rather than a descriptive name, but Triassic is now so deeply intrenched that no useful purpose would be gained by trying to change it. This system represents the first period of the Mesozoic era.

*Fig 195A (left)* Early Triassic paleogeography Nonmarine deposits, chiefly redbeds, are marked by horizontal black lines

*Fig 195B (right)* Middle Triassic paleogeography Symbols as above

*Fig 195C (left)* Late Triassic paleogeography Symbols as above Outcrops (black) in the Appalachian region mark the Newark fault troughs

## Physical History of North America

### *Newark Fault Troughs of the East*

After the Appalachian revolution the eastern half of North America, including the present continental shelf, was fully emergent for two long geologic periods Erosion was in progress throughout the whole region during Early Triassic time, as the Appalachian Moun-

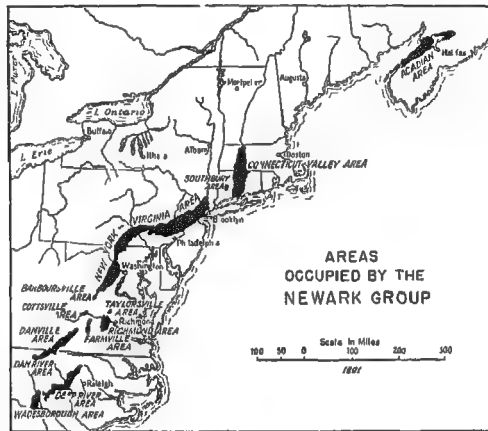



Fig 196 Map showing the position of the chief areas occupied by the Newark group After I C Russell, U S Geological Survey

tains were being reduced and the debris transported beyond the present margins of the continent (Fig 195) For the first half of the period there is no record save that of destruction of the older rocks by erosion Then, as though the compressive stresses had relaxed, the axis of the Appalachian chain began to be riven by great normal faults that produced a narrow chain of block mountains bordered by downfaulted troughs (Fig 196) The height and extent of the new block mountains are conjectural, but the structural troughs, which were filled as they sank, still retain a rich record of the time The northernmost basin lies in Nova Scotia, and others are distributed southward into North Carolina, a distance of about 1000 miles (Fig 195*C*) The Triassic strata formed in these troughs have been named the *Newark group* for the exposures near Newark, New Jersey, where they probably exceed 20,000 feet in thickness, and the structural troughs are known as the Newark basins

**The Connecticut Trough as a Type.** The Triassic trough of central Connecticut stands near the middle of this chain of basins and will serve well for further description It extends northward from New Haven across Connecticut and most of Massachusetts, its length being nearly 100 miles and its greatest breadth about 25 miles

Fig 197 Four stages in the development of the Triassic basin of central Connecticut View northward Length of sections, about 30 miles Modified from J Barrell

Block *A* shows the complex structure and rugged topography inherited from the Appalachian revolution, block *B* shows the beginning of Newark deposition after the region was largely peneplaned, block *C* shows the Newark fault trough fully developed through subsidence along the great fault, block *D* shows the final stage with the Newark deposits complexly faulted during the Palisade disturbance The modern structure of the region dates from this time Triassic strata stippled

The Triassic beds dip eastward at angles of 15° to 30° against a great fault that bounds the basin on the east and must have a maximum throw of about 3 miles (Fig 197)

The Triassic rocks of the basin are conglomerates, sandstones, siltstones, and shales, with interbedded flows of dark (basic) lava Perhaps half of the sediments are gray, but the most prominently exposed beds are red, and these commonly give the impression that the whole group consists of redbeds

The sediments are poorly sorted and irregularly bedded, sandstones grading laterally into siltstones or conglomerate All the coarse deposits are arkosic, and much of the feldspar is remarkably fresh The conglomerates are thickest and coarsest along the eastern margin of the basin and clearly represent fans built where torrential streams debouched from the highlands to the east In Connecticut the Newark group has an estimated thickness of 10,000 to 13,000 feet, and in New Jersey it may reach more than 20,000 feet, but it diminishes to 2000 or 3000 feet in the southern basins

The associated igneous rocks take the form of flows, sills, and dikes. They are mostly dark and fine-grained and are commonly identified as trap, but the larger sills have the texture of *dolerite*. The largest of these igneous bodies are flow sheets, three in number, which lie in the middle part of the series, each separated from the next by several hundred feet of sedimentary beds (Fig. 197*C*). The middle one of these reaches a thickness of about 500 feet and forms conspicuous ridges, such as the Hanging Hills of Meriden and Saltonstall Ridge. That each of these was a surface flow is clearly shown by the facts that (1) its upper surface is coarsely amygdaloidal and (2) the overlying sedimentary beds contain fragments of the scoriaceous lava but show no effect of heat as does the floor under the lava. These flows were remarkably free of explosive violence, for ash and bombs are known in only one small area near the Holyoke Range in Massachusetts. The lava must have been very fluid to spread in such flat and extensive sheets. Great numbers of dikes cut the underlying strata.

The middle third of the Newark group, associated with the lava flows, is generally finer-grained than the lower and upper part, and is predominantly dark gray in color, whereas the higher and lower beds are chiefly red.

No marine fossils have been found anywhere in the Newark group, but land plants and fresh-water fishes are locally abundant in the darker gray beds, and dinosaur tracks in the redbeds are more plentiful than anywhere else in the world. Ripple marks are common, and mud cracks cover many of the bedding planes. The imprints of Triassic raindrops are in many places associated with the footprints and mud cracks (Fig. 198).

With these facts in mind, it is not difficult to reconstruct the events that transpired here during the latter part of Triassic time (Fig. 197). The Connecticut basin was then a fault trough similar to the California trough which now lies between the Coast Ranges and the Sierra Nevada. A range of block mountains bordered it on the east, with a fault scarp facing the basin. Repeated movement along the great fault depressed the basin and elevated the mountains. Meanwhile the streams which reached the basin from the uplands dropped most of their sediment here, building fans along the eastern border and fluvial deposits over the floor of the basin. Before the igneous activity began, the basin was well drained by through-flowing streams, and much of the mud was carried away, while gravel, sand, and silt were dropped

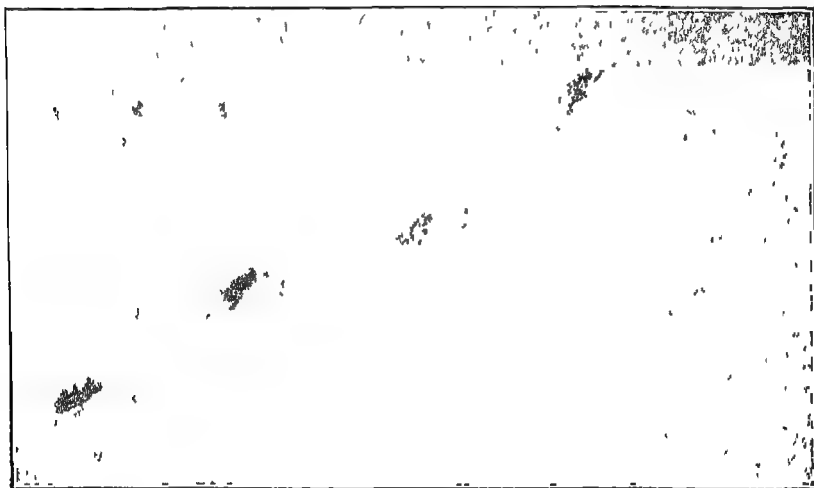
The uplands must have had plentiful rainfall to develop such a quantity of red mantle as is represented in these sediments, but the rains were probably seasonal Thus the mud that spread over the floodplains during wet seasons lay exposed to the sun during the dry months Dinosaurs crossed and recrossed, leaving their tracks in the mud The last spatter of passing showers also left imprints of raindrops where the mud was exposed and still soft During the dry sea-

*Yale Peabody Museum.*

FIG 198 Slab of Triassic sandstone from Turners Falls, Massachusetts, showing imprints of raindrops and tracks of two dinosaurs The larger tracks were made before the last rainfall, the smaller ones afterward

son the mud shrank and developed mud cracks and then was sunbaked and hardened, so that it could hold these surface features until they were buried by a new layer of sediment and preserved

Where the drainage was good and the ground water not close to the surface, the iron-stained sediments remained red After the first lava flow, however, the drainage was impounded, and for a considerable time swampy conditions obtained over much of the lowland, during that time vegetation accumulated with the sediments and in its decay reduced the iron oxide, producing gray or dark colors Such conditions held until after the last flow, and then, with better drainage, redbeds again accumulated over the basin

**Other Newark Basins.** The geology of the other Triassic fault troughs is, in general, like that sketched above In the Acadian area

the sediments are predominantly red, and there is a large trap sheet, but apparently only one. The dip here is northwest, and the bounding fault is on the west side (Fig. 196). In the New York-Virginia and Danville areas also the dip is westward, whereas in the Deep River and Wadesboro areas it is to the east. As we follow the basins southward from Connecticut, an important change is seen in the character of the sediments, since more and more of the sandstones and shales are greenish-gray instead of red. Finally, in the Danville area, there are interbedded coals which locally reach a thickness of 26 feet. This

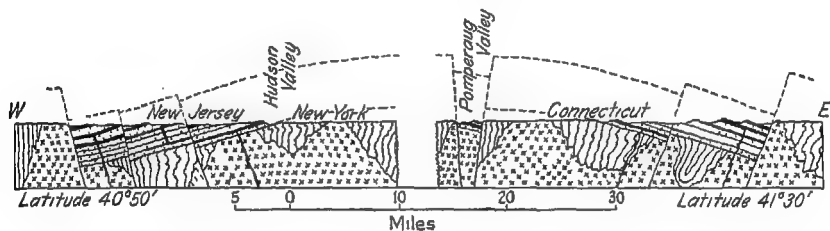



Fig. 199. Idealized section suggesting the probable structural relations of the Triassic basin of Connecticut and that of Pennsylvania and New Jersey. The western part of the section follows the line of latitude 40° 50′ and is about 50 miles south of the line of the section in Connecticut. Moreover, a section about 35 miles long is omitted in the center. In Connecticut the Triassic strata dip eastward toward a great fault, and in New Jersey and Pennsylvania they dip westward against another great fault. As here interpreted, these basins were on opposite sides of a great low arch. It is not certain that the Triassic sediments ever extended entirely across the arch. Triassic sandstone, dotted; trap rock, black; old metamorphic rocks, wavy lines or crosses. After C. R. Longwell.

may imply that the rainfall was more evenly distributed through the year in the southern basins, or that it was greater, or that the basins were not so well drained.

In the New York-New Jersey area, as in Connecticut, there are three great flows which may indicate equivalent periods of eruption in the two troughs (Fig. 199). Likewise there is a thick sill near the base of the group whose eroded margin now forms the Palisades of the Hudson River from New York City northward for a distance of nearly 50 miles. A few great dikes which cut across the margins of the area and extend out into the older rocks of the piedmont in southeastern Pennsylvania and central Maryland suggest that the volcanic activity was not confined to the structural troughs, but for the most part the Triassic volcanics are preserved only in the basins whose subsidence protected them from later erosion.

**Age of the Newark Group.** The fishes and plants of the Newark beds indicate that the entire group belongs to the later half of Triassic

time. In other words, at least half a period had elapsed after the folding of the Appalachians before the Newark basins began to form, and to trap sediments. Herein lies the explanation of the remarkable unconformity at the base of the Triassic. Wherever the basal contact has been seen, the Newark beds rest upon a surface of slight relief which cuts across the complex structures of the Paleozoic and older rocks. In Nova Scotia truncated folds of Pennsylvanian and older strata are overlain by the Triassic. In eastern Pennsylvania the strongly crumpled Ordovician limestones are in contact with the gently tilted redbeds in places where all the later Paleozoic rocks had been removed before the beginning of Newark deposition. In short, the Appalachian folds had been worn down and the region at least partially peneplaned during the late Permian and the earlier half of the Triassic.

### *The Arid Cordilleran Basin*

Triassic rocks are widely distributed through the Rocky Mountain region from Idaho and Wyoming southward across Utah, Colorado, Arizona, New Mexico, and western Texas. This is the greatest area of continental Triassic deposits in North America. Here continental redbeds predominate, though marine members of the older Triassic interfinger from the west. Bright red or maroon shales and cross-bedded red sandstones make colorful landscapes like the "Painted Desert" of Arizona and the "Great Red Valley" in the rim of the Black Hills.

The maximum thickness of these redbeds is found in the western part of the region, where, in southwestern Utah and northwestern Arizona, it amounts to 3000 to 4000 feet (see Fig. 200), and in general the system thins out to several hundred feet toward the east in Colorado and Wyoming. Beds of gypsum occur at various horizons in the red shales, especially in the eastern and northeastern parts of the region. There is also considerable volcanic ash in the redbeds of Arizona and Utah. Much of the detrital sediment came from the old crystalline uplifts of the Colorado Mountains in Colorado and northern New Mexico, for the Triassic formations become coarser-grained toward regions like the Uncompahgre Plateau (western Colorado), where they overlap against the ancient granites.

Throughout the Colorado Plateau a twofold division is generally recognizable. The lower portion, known as the *Moenkopi* (*mō' ĕn-kō pē*), is generally a soft formation of sandy shale and siltstone with local thin beds of salt and thicker ones of gypsum; it is mostly water-laid and rather evenly bedded. It grades westward into defi-

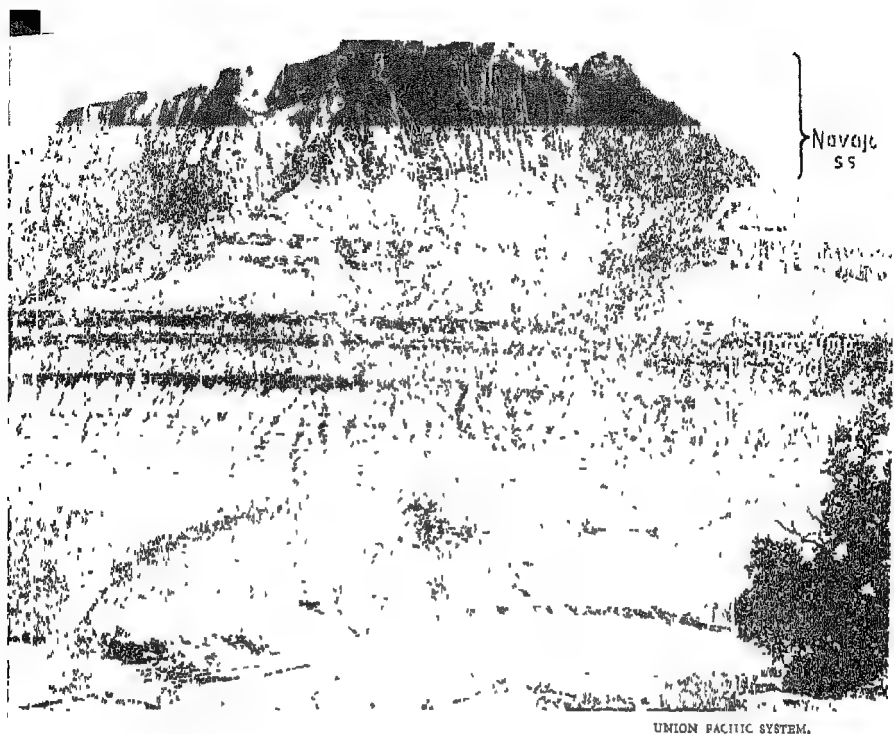



*Fig 200 West Temple of the Virgin, Zion National Park, Utah A 4000-foot wall of Triassic and Jurassic rocks carved out of the Colorado Plateau by the Rio Virgin Triassic rocks extend up to the base of the Navajo sandstone The ranch houses at the bottom indicate the scale For regional relations, see Fig 267, p 416*

nitely marine beds and finally into limestones in Nevada, but toward the east becomes a bright red shale and includes much sand In western Arizona it is a variegated formation with interbedded red and gray shales and siltstones

The upper series, known as the *Chinle* (*chĭn lee'*), is more sandy and generally more brilliantly colored, varying from white through reds, yellows, and blues It rests with an erosional unconformity on the Moenkopi over the eastern part of the plateau region, and there has a striking basal conglomerate, the *Shinarump* (*shĭ nă' rump*) (Fig 200)

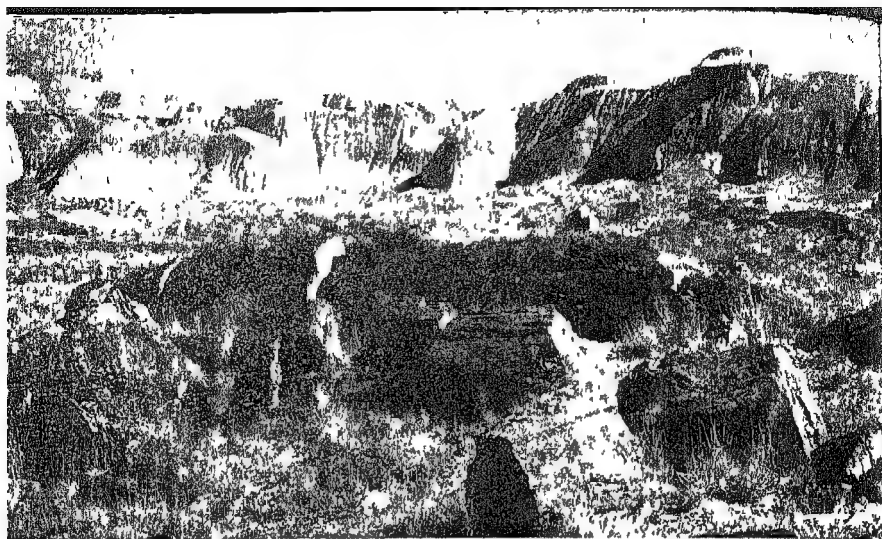
Fossils are extremely rare throughout the redbeds With the exception of those found in certain thin marine members that finger into the Moenkopi from the west, the only known fossils are remains or tracks of terrestrial or fresh-water animals, and petrified wood River clams occur here and there, and at certain horizons there are "bone beds"

JOSEF MUENCH

*Fig 201 Chinle formation showing variegated color and abundance of fossil wood Petrified Forest National Monument, Arizona*

of vertebrate remains These were partly labyrinthodonts (amphibia), but mainly reptiles of crocodile-like form and habits (phytosaurs), all of which inhabited the stream channels of the time Petrified wood is abundant locally in the Chinle sands, as at Petrified Forest, Arizona (Fig 201) The fossils, like the physical features of the rocks, therefore indicate that the redbeds were for the most part, at least, deposited above sealevel The gypsum that is so conspicuous in Wyoming may, however, represent evaporation in lagoons where the marine waters spread temporarily eastward from Idaho and Nevada The Moenkopi was deposited over a vast low alluvial plain sloping westward from the Colorado Mountains to the margin of a shallow epeiric sea, whose shore fluctuated back and forth over the western part of Arizona and Utah The Chinle was more completely independent of the sea and was spread by sluggish streams over a broad semiarid basin with seasonal rainfall, locally there were swamps and shallow lakes, whereas the higher ground surrounding the basins had scattered stands of conifers In the western lands there were explosive volcanoes, shedding ash far about

### *The Californian Sea and the Marine Trias of the West*

During Triassic time the Pacific Coast geosyncline appeared inside the margin of the continent, its axis running parallel to the present

Pacific Coast from California to Alaska It was not, however, so extensive in early Triassic time as it was from the middle of the period until well into the Cretaceous, when it was one of the major features of the continent and was repeatedly flooded by marine waters It appears to have been separated from time to time into two embayments by a positive area in the latitude of Oregon and Washington In this event, it is convenient to distinguish the *Californian Sea* in the United States and the *Columbian Sea* in British Columbia and Alaska West of the geosyncline lay island borderlands of unknown extent (Fig 195)

In California, Triassic formations, nearly all of marine origin, attain a thickness of 4000 feet or more and present a sequence of deposits and faunas that compare favorably with those in most parts of the world The greatest known section, however, is in south-central Nevada, where Triassic formations exceed 25,000 feet in thickness Here the Lower Triassic, some 3000 feet thick, consists of shales and sandstone; the Middle Triassic, about 12,000 feet thick, contains mostly volcanics with a small percentage of interbedded sediments, and the Upper Triassic, more than 10,000 feet thick, is made up chiefly of limestone and limy shale, with minor amounts of interbedded volcanics

In California and British Columbia the post-Triassic disturbances have so deformed these rocks that their areal relations are not well known

During early Triassic time the marine waters spread eastward from the Californian trough across Nevada and southern Idaho, where limestones and gray shales with abundant ammonites interfinger with the redbeds of the Cordilleran basin An arm of this sea extended far north into Canada along the borderline between Alberta and British Columbia (Fig 195*A*). Shallow arms of it may have spread temporarily as far east as the Black Hills of South Dakota to form the gypsum of the red Spearfish shales However, no marine fossils are known east of western Wyoming

During middle and late Triassic time marine water was restricted more definitely to the Pacific Coast geosyncline and did not spread east of Nevada (Fig 195*B, C*)

The Columbian Sea made its appearance in middle Triassic time, and it seems to have been studded with active volcanoes throughout the later part of the period In the region of Vancouver Island and the Queen Charlotte Islands the Upper Triassic alone has a thickness of 13,000 feet, but of this more than nine-tenths consists of submarine eruptives—lava flows, volcanic breccia, and tuffs With these are

interbedded zones of shale and quartzite having marine fossils. The sedimentary rocks are generally thin or lacking in the eastern part of the geosyncline but thicken westward, one such formation on Vancouver Island having a thickness of 2500 feet

Other volcanics of great thickness in western Nevada, northeastern Oregon, and west-central Idaho, originally thought to be Triassic, are now known to be largely Permian (see p 285)

In Alaska, the Triassic is represented by thick formations of limestone capped by an extensive black shale

### *Palisade Disturbance and the Close of the Period*

In the Appalachian region, faulting occurred repeatedly along a few great rifts, but the Newark group, with its interbedded lavas, accumulated with no more disturbance than a very slight eastward tilt due to the unequal depression of the floor

At the close of the period, however, general uplift began, accompanied by complex normal faulting that tilted the Triassic beds more steeply and broke them into innumerable fault blocks as suggested in Fig 197*D* Subsequent erosion has beveled these tilted blocks and etched out the resistant trap sheets into the prominent ridges of today, such as the Palisades of New York, the Hanging Hills of Meriden in Connecticut, and the Holyoke Range in Massachusetts All the structures involved, however, date from the faulting at the close of the Triassic, an orogeny known as the *Palisade disturbance* The regional uplift that accompanied the faulting brought an end to deposition in eastern North America until after Jurassic time

It is worthy of note that, although the Palisade disturbance followed the axis of the Appalachian system, the forces involved, as well as the structures produced, were almost the antithesis of those of the earlier deformation The forces of horizontal compression that made the Appalachians had apparently relaxed, to give way to normal faulting and broad uplift

In the western part of the continent, it is inferred that there was general emergence, since latest Triassic and most of early Jurassic time are not represented there, but no pronounced disturbance is known

## Triassic History of Other Countries

In a general view of the Earth, one of the most remarkable features of the Triassic is the almost universally emergent condition of the continents, and the extensive spread of nonmarine deposits, largely redbeds

In *South Africa,* nonmarine formations of great thickness (upper Karroo) are overlain by volcanics and shot through with basic intrusions of extraordinary magnitude (Drakensberg volcanics). The lower part of the series includes gray sandstones, siltstones, and shales with thin beds of coal and abundant plant remains, but the middle part consists of thick redbeds with mud cracks and a very interesting reptilian fauna. Overlying the redbeds come purer, wind-blown sands varying in thickness up to 800 feet. The succession of formations is interpreted to imply a growing aridity that resulted in desert conditions over a considerable area in South Africa before the close of the Triassic.[1] The basic igneous rocks intruded into this series have a present area of fully 220,000 square miles, and, before their erosion, covered at least 330,000 square miles in a great belt between latitudes 26° and 33° S. that extended from the east coast probably to the Atlantic. With a volume estimated as between 50,000 and 100,000 cubic miles, this constitutes one of the greatest known masses of basic intrusives. The time of its intrusion is either late Triassic or more probably early Jurassic.

The Permian basin west of the Urals in the U.S.S.R. also includes a vast area of redbeds (upper part of the Tatarian series) that have yielded striking vertebrate fossils.

In the Paraná basin of southern *Brazil,* late Triassic redbeds with reptiles similar to those of Africa are also overlain by enormous lava flows which still cover an area of some 300,000 square miles to a depth ranging from 400 to 2000 feet.[2] These lavas, like those of South Africa, may be dated as either late Triassic or early Jurassic.

In *England, Germany,* and *France,* the Triassic is represented chiefly by redbeds of nonmarine origin. In France these are salt-bearing, and those in Germany have gypsum. On the other hand, southern Europe was covered by a vast epeiric sea in the Tethyan geosyncline, which continued eastward through the Himalayan region and thence southward into the East Indian arc. Throughout this vast area, there is a fine development of marine Triassic, which is nowhere better displayed than in the dolomite peaks of the Tyrolean Alps. The dolomites of the South Tyrol are in places over 3000 feet thick and were almost wholly built by marine reef-making algæ.

## Climate

We have noted the evidence of widespread aridity in North America, South America, South Africa, and western Europe. On the whole,

arid or semiarid climate seems to have been remarkably widespread during the Triassic Perhaps this was partly due to the size of the emergent land masses, since the interiors of the continents, dependent for their moisture upon evaporation from the seas, include the chief deserts of the world At the same time, parts of the Triassic lands were well watered, just as parts of the present continents are humid

In view of the widespread Permian glaciation, it is noteworthy that no glacial deposits have been found in the Triassic rocks[+] The temperature had become mild long before the close of the Permian in places where glaciers had existed before This we may infer from the distribution of late Permian and Triassic vertebrates, all of which were cold-blooded, that is, without a device to keep their bodily warmth above that of their environment Modern reptiles and amphibia, without exception, become torpid and helpless when the temperature drops to near freezing Small species may take refuge in holes and hibernate, but all large species are confined to regions without frost For example, the alligators and crocodiles, the great land tortoises, the large lizards and boas, all live in the tropics or subtropics It is therefore highly probable that the dinosaurs as well as the sprawling reptiles and the large labyrinthodonts of the Triassic could not endure freezing weather Before the close of the period, corals had re-established themselves and were making small reefs in the seaways along the Pacific coast of America as far north as Alaska However, since these are of few kinds and the reefs are small, it is probably not safe to infer that the water was subtropical so far north

## Life of Triassic Time

**Land Plants.** The plants of this time are still imperfectly known, for less than 400 species have been described from all the world, and these are chiefly from the Upper Triassic formations This situation may be due to an actual impoverishment of plant life because of the harsh climates, but it more probably results from the fact that redbeds are a poor environment for the preservation of plants

In America we get two glimpses of the Triassic flora, one in the foliage preserved in the dark shales of the Newark group, particularly

[+] Triassic or Jura-Triassic tillites are reported in equatorial Africa west of Lake Tanganyika The tillites occur in the Lubilache formation Valves of *Estheria* occur It is not proved that this formation is of Triassic age, and it may after all be of Permian time See Coleman, *Ice Ages*, 1926, p 86

JOSEF MUENCH.

*Fig 202. Petrified logs in Petrified Forest National Monument, Arizona  This is near the base of the Chinle formation*

in the southern areas (Virginia and the Carolinas), the other in the petrified logs of the western redbeds, as at Petrified Forest, Arizona

The first is a swamp flora of ferns and scouring rushes, to which are added, where streams entered the swamps, the transported leaves of conifers and cycads that formed the forests on the uplands and slopes

The Petrified Forest of Arizona, on the contrary, has yielded chiefly petrified logs, although foliage has been found in several places,[7] recording cycadeoids and ferns that grew along the stream courses  The logs are of conifers, not unlike the great pines that now stand in stately grandeur upon the rim of the Colorado Plateau  Many of the logs are of noble size, some attaining a diameter of 10 feet at the base and a length exceeding 100 feet  It has been estimated that some of

these trees stood nearly 200 feet high (Fig 202) They now lie imbedded in the Chinle shale, petrified as agate

These two occurrences give a fair representation of what we know of Triassic land plants of the world as a whole The forests were then

Yale Peabody Museum

Fig 203 Glimpse into a Triassic landscape with characteristic plants and animals. Part of a great mural by Rudolph Zallinger

Plants 1, a broadleafed fern, *Macrotæniopteris*, 2, a primitive cycadeoid, *Wielandiella*, 3, a long-stemmed cycadeoid, *Palæocycas*, 4, a conifer, *Voltzia* Animals 5, a primitive reptile ancestral to the dinosaurs, *Saltoposuchus*, 6, one of the smallest of dinosaurs, *Podokesaurus* (length about 3 feet), 7, one of the largest of Triassic dinosaurs, *Plateosaurus*, a probable ancestor of the great sauropods of the next period (length about 20 feet), 8, a mammal-like reptile, *Cynognathus*

predominantly of conifers much like our modern evergreens, and of cycads (Fig. 203). The undergrowth consisted of ferns, tree ferns, and scouring rushes. The chief groups of Paleozoic plants were extinct, or nearly so. The seed ferns, so characteristic of the Coal Measures, had largely vanished, and the great scale trees are known only from rare specimens of *Sigillaria* in the early Triassic and a few other doubtful representatives. *Lepidodendron* is not represented, and cordaites were no longer conspicuous.

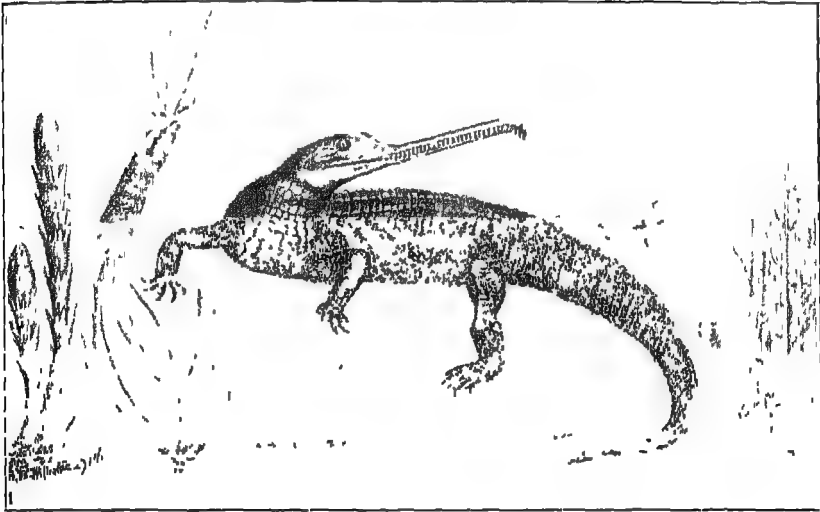



Fig. 204. A Triassic phytosaur, *Rutiodon*. Plants in the foreground are rushes, and the tree in the background is a cycad. After S. W. Williston. The phytosaur had a length of 10–12 feet.

**Land Animals. The Beginning of a Reptilian Dynasty.** The vertebrates of the lands were now varied and evolving rapidly. While the labyrinthodonts attained their culmination in size and variety, they were already far surpassed by the *reptiles*, which showed themselves adapted to all conditions of life on the lands, and early in the period began to invade the seas and compete with the fishes as do the modern seals and whales. Phytosaurs were common in the streams, and several other orders of reptiles, now extinct, were adapted to life on the lands. The phytosaurs resembled the modern gavials in appearance and habits but were not closely related to crocodiles. Their bones are found in association with river clams and lungfishes. One species from western Texas had a length of 25 feet. All the phytosaurs were confined to the Triassic period (Fig. 204).

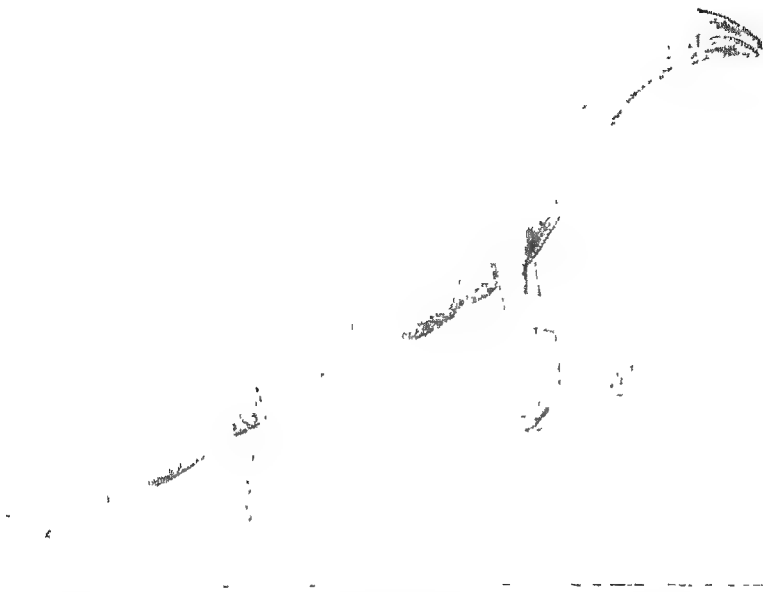



*Fig 205 A Triassic dinosaur, Anchisaurus colurus, after a model by R S Lull, based on a skeleton in Yale Peabody Museum The animal was about 6 feet long*

*Dinosaurs* (Gr *deinos,* terrible, + *sauros,* reptile) made their appearance in the Triassic and by the middle of the period outnumbered all other kinds of reptiles and held complete sway over the lands—a dominion they were destined to hold until the close of the Mesozoic era Unlike other reptiles, they were adapted to a running locomotion, carrying their bodies up off the ground like mammals, with the legs under the body, not at its sides Other reptiles sprawl This is the only obvious feature that ties the diverse types of dinosaurs together as a natural group, for they vary by the widest extremes in size, bodily form, and habits Indeed, they constitute, as we now know, not a single great order of reptiles but two that are only remotely related, having had very different origins

Compared with the giants of later Mesozoic ages, the Triassic dinosaurs were hardly "terrible reptiles," for nearly all of them were slender of build and few reached a length of more than 10 or 15 feet Almost all the known Triassic species were bipedal (Fig 203) and shaped somewhat like a kangaroo, with powerful hind legs and a thick, powerful tail which aided in balancing the body as they ran The bipedal dinosaurs did not leap like a kangaroo, however, but ran like an ostrich The nature of their abundant tracks makes that quite certain

The side toes on the hind feet were already vestigial in most of the Triassic species, so that they made three-toed footprints that were for a long time mistaken for bird tracks Although the dinosaurs were very numerous in the eastern United States, skeletal remains are extremely rare, because the redbeds were a poor environment for the preservation of bones As the dinosaurs crossed and recrossed the mud flats of the Connecticut trough, however, they left an amazing record, not of dead but of living creatures, now hurrying in search of food or water and again stopping to rest and to leave in the soft mud an impression of the body and the tiny front feet The best-known American form is *Anchisaurus* (Fig 205), a slender, graceful animal that reached a length, over all, of probably 5 to 8 feet, its birdlike tracks have a length of 3 or 4 inches Some of the similar tracks 5 or 6 inches long indicate larger species The largest track of all (*Otozoum*) is that of a ponderous type, probably larger than an elephant, for its foot was more than 18 inches long and almost half as broad

In 1947 a rich deposit of small Triassic dinosaur skeletons was discovered near Abiquiu, New Mexico [4] Dinosaurs similar to those of America were also present in Europe, and nearly complete articulated skeletons of carnivorous dinosaurs were discovered in the Upper Triassic of China in 1947 [5]

South Africa had, besides the dinosaurs, several other orders of primitive reptiles, some of which were squatty and heavy of build More interesting than all other reptiles of the time were the therodonts, a group from which the primitive mammals evolved during the Triassic Some of these, like *Cynognathus* (Fig 206), form the closest

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*Fig 206 A mammal-like reptile, Cynognathus, from the Triassic beds of South Africa A painting by F L Jaques, made under the direction of W K Gregory*

approach to true mammals in every detail of the skeleton The teeth, for example, are differentiated and the dentary bone forms nearly the entire lower jaw This group of mammal-like reptiles is known in America from only two tiny jaws, each about the size of that of a rat (Fig 207) These were found in one of the Triassic coal mines in North Carolina, and were for many years supposed to belong to true mammals

Teeth and jaws occurring sparsely in the late Triassic (Rhætic) beds of Germany resemble those of a primitive group of mammals known as *Multituberculata* (p 464 and Fig 298), and these were long regarded as the earliest known mammal remains Discovery of a nearly complete skull in the late Triassic of South China (Fig 208) and critical restudy of the previously known genus *Tritylodon* have shown that these are still on the reptilian side of the fence, though possibly representing the group from which the multituberculates evolved [6] At present, therefore, no mammals are known from Triassic rocks [7]

Fig 207 Lower jaw of a small mammal-like reptile, *Dromatherium*, from the Upper Triassic beds in North Carolina After George G Simpson Twice natural size

**Return of Reptiles to the Sea** Marine reptiles are known in the Lower Permian rocks of South America and South Africa, but they did not become common until late in Triassic time Dolphin-like reptiles called *ichthyosaurs* (Gr *ichthys,* fish) appeared in the late Triassic seas and developed rapidly into one of the dominant groups of marine animals of the Mesozoic era They were already abundant in the late Triassic of California and Oregon, where the largest species was about 30 feet long, and they were probably the largest animals in the world at that time The ichthyosaurs had a fishlike contour with a laterally compressed tail and flipper-like limbs (Fig 223) They were undoubtedly fast swimmers, able to capture fish or the ancient squids (belemnites) and ammonites of their time

Another group of marine reptiles, the *plesiosaurs* (Gr *plesios,* almost), made its appearance in Europe at this same time Unlike the sleek ichthyosaur, the plesiosaur was a broad-bodied, short-tailed creature that paddled clumsily like a marine turtle (Fig 224) He made up for this shortcoming, however, by a long and very agile neck, which enabled him to dart out his head and take by surprise unwary animals that came near

Both ichthyosaurs and plesiosaurs were descended from land reptiles and represent two migrations back to the sea The adaptation doubtless began in semiaquatic habits like those of the hippopotamus or the seal, but before the close of the Triassic both tribes of reptiles were remarkably adapted to a roving life in the open sea The structure of the limbs proves their terrestrial ancestry, for it shows all the elements of the pentadactyl limb of a land animal, only changed in

Fig 208 Oblique view of the skull of a mammal-like reptile, *Bienotherium*, from the late Triassic beds of South China, as restored by its discoverer, Dr C C Young

proportions so as to make finlike flippers instead of walking legs It is a striking fact, confirming the expectation of evolutionary theory, that the limbs of the Triassic species are much more like those of land animals than are those of the more perfectly specialized forms of the Jurassic

**Marine Invertebrates.** The seas now swarmed with ammonites (Pl 13, figs 6–14) of which there were many kinds, some far larger than any in the Permian They were not only the most beautiful and characteristic shelled animals of the Mesozoic seas, but also the highest expression of invertebrate evolution in agility and strength The rapid expansion of the group during the Triassic continued to near the close of the period, when a very rapid dying out almost caused their extinction However, one genus (*Phylloceras*) with several spe
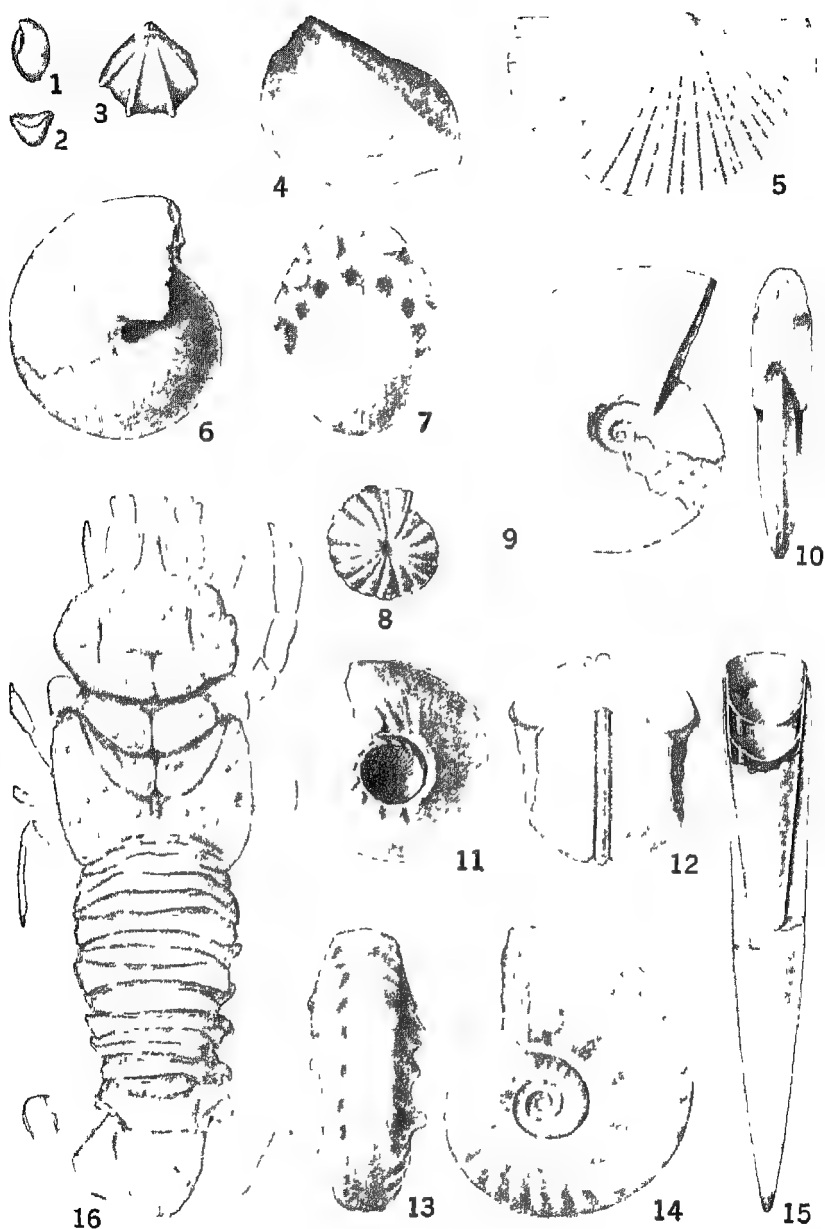
Plate 13 Triassic Brachiopods (1–3), Pelecypods (4, 5), Cephalopods (6–15), and Crustacea (16)

Figs 1, 2, *Aulacothyris angusta* (side and front views), 3, *Tetractonella trigonella*, 4, *Myophoria kefersteini*, a forerunner of the Trigonias, 5, *Daonella americana*, 6, 7, *Paratropites arnoldi*, 8, *Leconteiceras californicum*, 9, 10, *Meekoceras gracilitatis*, 11, 12, *Tropites subbullatus*, 13, 14, *Ceratites spinifer*, 15, *Atractites macilentus*, the shell of a primitive belemnite broken to show internal chambered portion, 16, *Pemphix sueuri*, the oldest known

cies managed to survive into the Jurassic and to give rise to another great evolution of forms in that period.

The decline of so great and adaptive a group is difficult to explain Possibly they were unable to adjust themselves quickly to the attack of the rapidly evolving marine reptiles, which certainly preyed upon them

Squidlike cephalopods (Pl 13, fig 15) appeared early in the Triassic and became very common in the Jurassic Among the other molluscs, both *clams* (Pl 13, figs 4–5) and *gastropods* were in the ascendancy Modern types of echinoids and starfishes, and small lobsters (Pl 13, fig 16) originated at this time but were not common until later

*Reef-building corals* related to living kinds appeared in Late Triassic time and contributed to the thick dolomites and limestones of the Alps and the Himalayas They were widely distributed through the Tethyan geosyncline of Eurasia and also spread along the Pacific coast of North America from California to Alaska *Brachiopods* (Pl 13, figs 1–3), though still common in Tethys, had suffered a very great decline elsewhere from which they failed to recover They were never afterward common in America

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## Collateral Reading


*The Dinosaur Book;* by Edwin H Colbert American Museum of Natural History, Handbook No 14, 1945, pp 1–156

Entertaining and finely illustrated account of Mesozoic life

*The Fossil Forests of Arizona*, by George P Merrill 23 pages Washington, 1911

*Walks and Rides in Central Connecticut and Massachusetts*, by Chester R Longwell and Edward S Dana 229 pages New Haven, 1932

## CHAPTER 15

# THE JURASSIC PERIOD

During the Jurassic period epeiric seas gradually spread over Europe, with a life that was astonishingly rich and varied In these seas there was deposited more than 3000 feet of the most richly fossiliferous of all the Mesozoic rocks These have been the training ground for many European geologists, and have given us an understanding of some of the fundamental principles of stratigraphic geology

FIG 209 William ("Strata") Smith (1769–1839), "Father of English Geology"

It was here, for example, that William Smith first discovered the use of fossils in proving the age of the rocks and correlating those of the same age from place to place Smith was a surveyor, concerned with mapping estates, draining swamps, and laying out canals across southern England, where the gently tilted Jurassic limestones and shales are superposed "like slices of bread and butter" Many of these beds were quarried for building stone and could be recognized by lithologic peculiarities from quarry to quarry For years Smith collected the beautifully preserved fossils which weathered from these rocks, not with any appreciation of their significance but merely because they were curios—to him this was a hobby, just as the collecting of stamps or coins is to many another However, as he was cataloguing his treasures one day in 1798, he perceived for the first time that a given bed always yielded the same kinds of fossils wherever he found it exposed, and that every other formation had different species This being the case, he reasoned that he could identify the beds in other quarries by their fossils As we have seen, it was only a few years after the discovery of this principle that stratigraphic geology had its great development in Europe, and that most of

the geologic systems were worked out and named These advances would have been impossible without the principle discovered by Smith, who has been called the "Father of English Geology" (Fig 209)

From the studies of the abundant Jurassic marine faunas came also the first clear ideas of climatic zones in the geologic past and of world paleogeographic maps

Many of the Jurassic limestones in England are oölitic, and Smith therefore called this the "Oolite series", but the German geologist, von Humboldt, and later the French geologist, Alexandre Brongniart, applied the name Jurassic to equivalent limestones in the Jura Mountains, between France and Switzerland Smith's term is still used informally for part of this system in England, but the name Jurassic has long since gained universal acceptance for the system

## Jurassic History in America

**Erosion Prevails in the East.** In contrast to its great development in Europe, the Jurassic is more restricted than any other system in North America Not a trace of these rocks is exposed east of the Great Plains, and it is probable that the entire eastern half of the continent was emergent and undergoing erosion throughout the period Nothing is known directly of the old borderland, Appalachia, but it probably began to founder and sink beneath the sea before the end of the Jurassic

Undoubtedly the Appalachian region had considerable relief after the Palisade disturbance, but there is evidence to indicate that before the close of Jurassic time the whole region was essentially peneplaned

**Beginning of the Rocky Mountain Geosyncline** A new geosyncline took form during Jurassic time along the course of the present Rocky Mountains, and both ends of it were invaded by the sea (Fig 210) The southern embayment, crossing Mexico, developed late in the period and reached northward to western Texas (Malone Mountains) and southeastern Arizona Here the Jurassic formations are largely calcareous and bear ammonites indicating a direct connection with Europe but no close relation to the northern (Sundance) or the California seaways This southern part of the trough is commonly known as the *Mexican geosyncline*

The northern embayment is best known by the widespread Upper Jurassic formations which indicate an arctic sea spreading southward across Alberta and eastern British Columbia into the states of Mon-

*Fig 210A (left) Early Jurassic paleogeography Symbols as in Fig 154*

*Fig 210B (right) Middle Jurassic paleogeography*
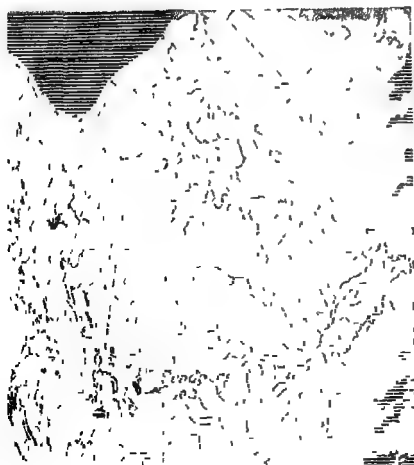
*Fig 210C (left) Late Jurassic paleogeography Jurassic overlap on the Gulf states is recorded in deep wells The Mesocordilleran geanticline now separates the Sundance from the Columbian geosyncline*

tana, Idaho, and Wyoming, reaching for a short time as far south as central Utah and as far east as the Black Hills of South Dakota (Fig. 210*C*) In the northern Great Plains the chief marine record of this time is the *Sundance formation*, and for it this vast embayment has been named the *Sundance Sea*

Middle and Lower Jurassic beds exposed locally about Fernie, British Columbia, indicate that the embayment temporarily reached this far south early in the period, but little is known of the distribution of these early deposits (Figs 210*A*, *B*)

The middle part of this geosyncline was not submerged during Jurassic time, but much of Utah and parts of adjacent states subsided as an arid basin Before the arrival of the Sundance Sea, thick desert sands had accumulated in Utah and Arizona, and during its stay the sediments continued to converge into it from the bordering uplands Here, then, we find marine beds interfingering with desert deposits The marginal lagoons at the south end of the Sundance Sea were from time to time land-locked and reduced to a highly saline condition, so that gypsum was precipitated Thus, south of the limit of marine fossils, there are beds or lenses of gypsum interbedded in the continental sediments Following the retreat of the Sundance Sea, the streams that crossed the basin from the rising lands farther west laid down over much of the geosyncline a mantle of alluvium that buried the most spectacular of all American dinosaurs This is the *Morrison formation*

The Jurassic period thus saw the beginning of the great geosyncline that dominated the western scene throughout the rest of the Mesozoic era and, during the Cretaceous period, was occupied by a vast sea that extended from the Arctic to the Gulf. Out of this trough the Rocky Mountains were formed at the close of the era, and for this reason it is known as the *Rocky Mountain geosyncline*

**Persistence of the Pacific Coast Geosyncline** The Californian and the Columbian geosynclines persisted, with minor changes, throughout the Jurassic period, and both received an impressive thickness of detrital sediment and much volcanic material A chain of active volcanoes extended from California to southern Alaska during the early part of the period, and their activity was resumed on a grand scale during Late Jurassic time Many of the volcanoes arose out of the seaways In British Columbia submarine volcanics range up to 3000 feet in thickness, and in eastern California the Mariposa formation also includes immense outpourings of basic lava

The seas which occupied these geosynclines were at times distinct, but during much of the period they were connected across eastern Oregon and Washington.

**Nevadian Disturbance.** Over much of the world the Jurassic lands were stable, but along the western border of North America, Late Jurassic time witnessed intense and widespread deformation accompanied by the intrusion of immense batholiths of granite This orogeny has been named the *Nevadian disturbance,* but many American geologists think it deserves to be called a revolution

Fig 211 Outcrops (*in black*) of the late Jurassic-early Cretaceous batholiths of western North America

At this time the Pacific Coast geosynclines were crushed by compressive forces from the west, and their thick deposits were thrown into long ranges of fold mountains The effects of the disturbance can be recognized as far east as the Wasatch Mountains in eastern Utah,[1] but the area of intense deformation was in western Nevada, California, Oregon, Washington, and the western part of British Columbia

The distribution of the late Jurassic batholiths is indicated in Fig 211 That of the Sierra Nevada is nearly 400 miles long and 80 miles wide, but the Coast Range batholith is still greater, extending for 1100 miles north of the Canadian border Neither of the vast masses of granite is actually a single intrusion, each is a complex of closely related intrusions * The emplacement of the granite probably followed shortly after the main folding and was a feature of the Nevadian disturbance The net result of the compression and the intrusion was to leave the Jurassic and older rocks isoclinally folded and strongly

* The Coast Range batholith is, for the most part, not yet closely dated and may include intrusions of both late Jurassic and early Cretaceous date

metamorphosed in eastern California and parts of British Columbia The heat and pressure, as well as the gases and fluids ascending from such vast bodies of magma, led to severe metamorphism of the sedimentary rocks into which the intrusions were driven The gold-quartz veins of the "Mother Lode" belt in the Sierra Nevada were formed by the ascending solutions, which penetrated the Jurassic slates then forming the roof of the batholith

The precise date of the Nevadian disturbance is still uncertain Like all great orogenic movements, this one undoubtedly developed over a considerable span of time, reached its climax, and then died away It is unlikely, furthermore, that the climax came simultaneously over so vast a region Since late Jurassic formations are involved in folding and intrusion that did not affect the Cretaceous formations, it is evident that the Nevadian disturbance culminated at the end, or near the end, of the Jurassic period

Both the Mariposa formation of California and the Galice formation of Oregon, for example, are intensely metamorphosed, and both bear ammonites of Kimmeridgian age (next to the youngest in the Jurassic time scale of Europe) It is alleged by Taliaferro, however, that in Oregon the Galice formation is unconformably overlain by less deformed beds of the Knoxville formation, which bears fossils of Portlandian age (latest of the European Jurassic), and that here, at least, the climax of the disturbance came before the close of the period [2] Much more evidence is needed to prove whether this relation is general in western North America

## CHARACTER OF THE JURASSIC FORMATIONS

**Redbeds and Dune Sands of the Colorado Plateau.** Over the states of the Colorado Plateau the Jurassic system is represented by redbeds and dune sands that attain a maximum thickness of 3000 feet or more The lower division has been named the *Glen Canyon group* for its magnificent exposures in the towering walls of Glen Canyon of the Colorado The upper part is known as the *San Rafael group* for its exposures in San Rafael Swell, central Utah

The *Glen Canyon group* is composed almost entirely of fine-grained pure quartz sand of light gray or pink color The bedding is generally obscure, and the sandstone appears exceptionally massive It is everywhere a cliff maker, outcropping in "unscalable walls of commanding height" (Figs 200, 212) Near the middle of the group there is a zone of thin-bedded slabby sandstone which separates two mas-

sive formations, the *Wingate sandstone* below and the *Navajo* above In the plateau region these normally outcrop in two colossal cliffs with a bench between Over great areas the Navajo and Wingate formations are a solidified dune sand in which the swinging curves of gigantic cross-bedding betray eolian origin (Fig 213) Rainbow Natural Bridge is carved from this sandstone

These formations are almost entirely unfossiliferous, and their precise age is uncertain Recently a small bipedal dinosaur was found in the Navajo sandstone near Kayenta, Arizona, and tracks of dinosaurs have been discovered at a few places in the slabby sandstone between the Wingate and Navajo formations The Wingate sandstone may prove to be of late Triassic age

CARL O DUNBAR

*Fig 212 Towering cliffs of Navajo sandstone, Zion National Park, Utah In the distance at the left, The Great White Throne*

The *San Rafael group* is formed of red sandstones and siltstones and red shales into which there interfinger from the northwest two great wedges of gray marine shales and sandstones. It also includes one massive pure sandstone member like the great dune sands below. The redbeds were deposited on a low alluvial plain in an arid basin, and the marine members that interfinger from the northwest mark temporary incursions of the Sundance Sea. The group has a thickness of about 1500 feet.

All these formations of both the Glen Canyon and the San Rafael groups thin out by overlap on the old Pre-Cambrian granite of the Uncompahgre Plateau and other elements of the Colorado Mountains in western Colorado. The increasing coarseness and the presence of locally derived boulders indicate that much of this detrital material was coming from that region, but, since the sandstones thicken toward the west, it is probable that the Mesocordilleran geanticline lying

CARL O. DUNBAR

*Fig. 213. "Frozen dunes" in the Navajo sandstone near the south entrance to Zion National Park, Utah.*

C. H. DANE, U. S. GEOLOGICAL SURVEY
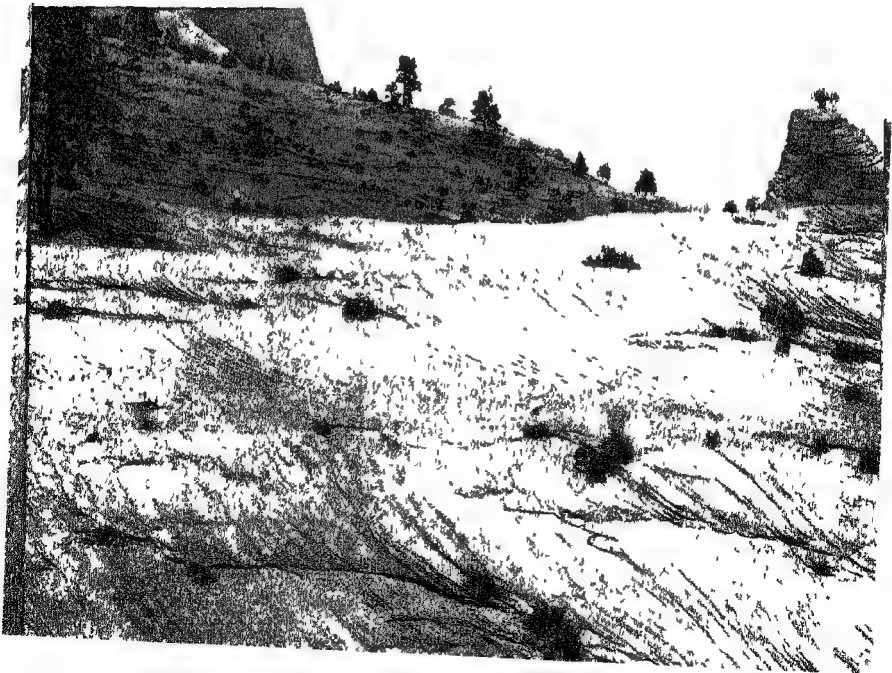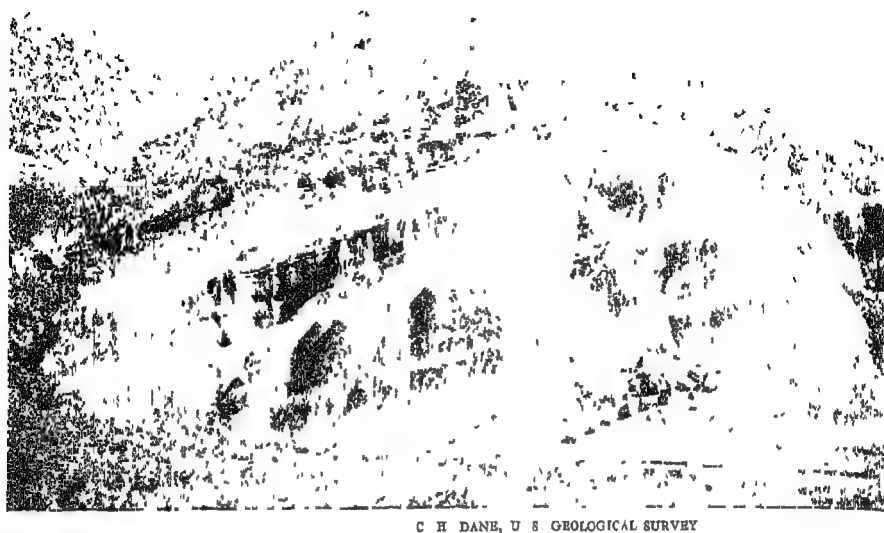
*Fig. 211. Upper part of the Morrison formation near Cisco, Utah, comprised of variegated shale and sandstone.*

between the Rocky Mountain and the Californian seaways (Figs. 210*C*, 230*B*) was supplying a large share of the sediment.

**Marine Strata of the Sundance Seaway.** The Sundance formation of the northern Great Plains is a conspicuous key horizon, lying between the unfossiliferous redbeds of the Triassic and the continental sediments that rest upon it. Over this area it is normally only 200 to 300 feet thick. It consists mostly of sandstone and shale, but there are limy zones filled with fossil oysters and other clams, as well as the shells of belemnites and other cephalopods, and, rarely, skeletons of ichthyosaurs. The water was evidently shallow, since the sediments varied locally from nearly pure sand to mud. In places the shales are partly red.

Traced westward into Idaho, the Jurassic beds thicken to 5000 or 6000 feet and are divisible into four distinct formations. This great increase in thickness is due partly to the fact that deposition began earlier and continued longer in the geosyncline than it did farther east. It may be also that more rapid subsidence allowed the sediments derived from the west to come to rest more readily on the floor of the geosyncline, so that accumulation there was more rapid.

**Morrison Formation and Its Dinosaurs.** All the gigantic dinosaurs of the American Jurassic have come from a single formation (Figs. 214, 215) that was deposited as a blanket of fluvial sediments over the rest of the Jurassic formations in the Cordilleran region. The formation is named for its exposure at Morrison, near Denver, but it extends far to the north into Montana, west into Utah, and south into New Mexico, originally covering more than 100,000 square miles of the Rocky Mountain region. In spite of this great extent, it is usually less than 400 feet thick.

The Morrison consists of shales, siltstones, and sandstones with local conglomerates, all of which intergrade laterally, as is the habit

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*Fig. 215. Excavating a dinosaur skeleton in the Morrison formation near Shell, Wyoming.*

of continental deposits, so that it is impossible to follow a single bed over a considerable distance The coarser sediments are commonly irregularly bedded and cross-laminated The color varies locally from greenish-gray to black or lavender or pink or even white No marine fossils have ever been found, but more than 150 kinds of terrestrial animals and land plants are known from these beds These include the greatest of all dinosaurs Sixty-nine of the species are dinosaurs, 25 are tiny primitive mammals, 3 are crocodiles, 24 are river clams and land snails, and 23 are plants

From these facts we can picture the region at the time of deposition in a setting not unlike that of the present basins of the Amazon or Paraná rivers It was a low alluvial plain crossed by sluggish streams heading in the distant highlands to the west, whence came heavy loads of mud and sand Here and there swamps or small lakes interrupted the courses of the braided streams The shifting sands and gravel bars along the channels gave rise to deposits of cross-bedded sandstone and conglomerate, while the finer mud and silt that settled over the floodplains produced the varicolored shales The climate had become more humid with slight emergence of the whole region from the sea, so that vegetation spread over the landscape and animal life was abundant In southwestern Colorado and New Mexico the lower part of the section generally assigned to the Morrison includes eolian sand and gypsiferous beds, but these are now known to be equivalent to part of the Glen Canyon group and older than the Morrison formation proper [d]

The geologic date of this formation is difficult to prove It overlies beds (Sundance) dated certainly as early Late Jurassic and is in turn overlapped (in Oklahoma and southeastern Colorado) by beds of late Early Cretaceous age (Washita) So far as the stratigraphic evidence goes, therefore, the Morrison may be Late Jurassic or Early Cretaceous The fauna, though abundant, can not be compared with anything in the standard marine sections of the world, and we still know little about the land life of the Late Jurassic and Early Cretaceous of America except what is recorded in the formation in question A comparison of the dinosaurs of the Morrison with those of the Jurassic and Cretaceous of Europe, however, brings out rather convincing evidence of Jurassic affinities (especially among the Stegosauria), and this is supported also by a comparison of the mammals [1]

Curiously, the best evidence on the age of the Morrison is found nearly half-way around the Earth, in East Africa, where there are

beds bearing dinosaurs closely like those of the Morrison, interbedded with marine zones carrying undoubted Jurassic ammonites Although it is possible that the Morrison and the East Africa (Tendaguru) formations are not strictly equivalent, the balance of the evidence favors the assignment of the Morrison to the Late Jurassic

**Rocks of the Pacific Coast Geosyncline** Jurassic rocks are extensively exposed in California but in widely separated areas where they have escaped the several later periods of deformation and deep erosion In most places, they have become involved in very complex structures and metamorphosed to such an extent that fossils are obscure With these fragments of the record, it is impossible to restore a complete picture of the Jurassic history of California Suffice it to say that the sediments were very thick and almost entirely detrital, proving that the bordering lands were sufficiently elevated to be undergoing extensive erosion

In eastern California the *Mariposa slates* and interbedded volcanics reach a thickness of possibly 10,000 feet Mount Jura at the northern end of the Sierra Nevada presents a very complete Jurassic section, with fifteen formations ranging from Lower to Upper Jurassic and containing volcanic tuffs and agglomerates of various ages throughout the period, and recently a still finer and more complete section was discovered in eastern Oregon In Shasta County, California, the Jurassic is represented by the *Knoxville* sandstone and shale, which may total 10,000 feet in thickness, and includes continental beds with land plants, as well as marine zones with the peculiar arctic clam, *Aucella* (Pl 14, fig 6) The *Franciscan series*, which is widely spread in the Coast Ranges both north and south of San Francisco, contains radiolarian cherts and interbedded sandstones probably of middle and later Jurassic age, with an estimated thickness of 15,000 feet These sediments become coarser toward the west, suggesting their origin from the marginal land, Cascadia In the vicinity of Vancouver Island, also, thick detrital Jurassic formations are found

The great thickness and the detrital nature of all these western formations show that the disturbance culminating in the Nevadian mountains was already being felt during Late Jurassic time, and that the Pacific Coast geosyncline was profoundly depressed as the bordering geanticline arose

Southern Alaska has a great development of Jurassic rocks, though they have not been studied in detail Marine formations of Early,

Middle, and Late Jurassic age are known, and much volcanic material is associated with these, especially in the lower and upper portions.

## Climate

As we have seen, desert conditions continued in the southern part of the Cordilleran region, where the Navajo sandstone is one of the greatest dune-sand formations of the entire Earth. This, however, was apparently a local condition and may have been due to the fact that the region was lower than the western land mass which cut off the moisture-bearing winds. In many other parts of the world, the climate was decidedly more humid than it had been in the Triassic, and gray or dark sediments with coal beds accumulated in the lowlands. For example, the Middle Jurassic is coal-bearing in Mexico, California, Alaska, Greenland, Spitzbergen, Europe, Siberia, India, China, Australia, South Africa, and Antarctica. There was nothing like the wide distribution of redbeds that we observed in the Triassic, and no important salt or gypsum deposits are known like those of the two previous periods. Outside of North America the epeiric seas were again very extensive, and with this spread of marine water went, apparently, milder and moister climate.

The temperature appears to have declined somewhat at the close of the Triassic, though not enough to bring on glaciation. The middle and later parts of the Jurassic, on the contrary, were marked by very mild climate even in high latitudes, and probably by subtropical conditions over most of the United States and southern Europe.

The lowering of the temperature at the end of the Triassic is inferred from the great decline of the ammonites, the dwarfing of the Early Jurassic insects, a decided reduction and geographic restriction of the reef corals of Early Jurassic time, and the marked development of growth rings in the woods of that time in temperate latitudes.

That the Middle and Late Jurassic climates were milder and more equable than the present ones must be inferred from the distribution of both animals and plants. Toward the close of the period the greatest of all dinosaurs ranged over the western United States at least as far north as Montana, and in Asia they were at home in Mongolia, where winter temperatures now fall far below zero. Yet the dinosaurs very probably could not endure freezing weather. Reefs of corals, sponges, and bryozoa abound in the Jurassic rocks, corals occurring some 2000 miles north of the present range of similar forms. The distribution

and character of the Mid-Jurassic land plants are thought also to indicate a warm, moist climate over much of the Earth. Furthermore, the insects of the early Upper Jurassic formations are much larger than those of the Lower Jurassic.

## Economic Resources

**Coal.** The Jurassic is an important coal-producing system, if we consider the world at large. Extensive areas in Siberia are underlain by Jurassic coal of economic importance, and in Tasmania and Australia the chief coal measures are the Jurassic rocks. There are also important coals in Spitzbergen and smaller deposits in various parts of Europe and southern Asia. In North America, however, there is no workable Jurassic coal except that of eastern Greenland.

**Gold.** The gold that attracted the "Forty-Niners" and led to the rapid settlement of California has its source in the gold-quartz veins formed in the Jurassic slates along the western slope of the Sierra Nevada. The placer gold that the early settlers panned from the streams was concentrated in the river gravels during Cenozoic times, but it came originally from the Jurassic veins and was freed during their erosion. A long, narrow belt of Jurassic rocks containing gold veins and extending for 120 miles along the western foothills of the Sierra Nevada is called the "Mother Lode" belt.

Up to 1937, California had produced about $1,850,000,000 worth of gold, most of which came from the veins of late Jurassic origin or from placers derived therefrom. In 1939, the state produced 1,424,719 ounces of gold with a value of $49,865,000, which is approximately one-third of the production of the entire United States.

## Life of the Jurassic Period

**Forests of Evergreens.** The floras of the Jurassic, although in the main a continuation of those of the Late Triassic, were in important respects different from modern ones. So far as known, they consisted of scouring rushes, herbaceous and tree ferns, cycadeoids, gingkos, and abundant conifers (Fig. 216). The forests presented thick stands of pines and other conifers, mingled with gingkos and tree ferns, with an undergrowth of herbaceous ferns and rushes, while the more arid slopes presented an open growth of cycadeoids and ferns. It seems to have been an evergreen assemblage, still lacking the deciduous hardwood trees like those of our modern forests, though it probably in-

cluded forerunners of these, as yet unknown Modern flowering plants, that is, angiosperms, are not certainly known from the Jurassic, though a few inadequately known types have been suspected of representing this great group. The cycadeoids, however, were truly flowering plants

A remarkable feature of the Mid-Jurassic floras is the wide distribution of many of the species If we exclude the cycads, about half the plants known in North America are found also in Japan, Manchuria, Siberia, arctic Alaska, Spitzbergen, Scandinavia, or England Even the plants collected by the Shackleton expedition in Louis Philippe Land below Cape Horn (in latitude 63° S ) are practically the same as those of Yorkshire, England In this cosmopolitan distribution of the land plants, there is striking testimony of mild, equable climates

*Cycadeoids* (Figs 216–218) appear to have been the most characteristic plants of the Jurassic, as they were of the Triassic In fact,

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*Fig 216 A Jurassic landscape Part of a great mural by Rudolph Zallinger Plants 1, a fern, Matonidium, 2, scouring rush, Equisetites, 3, a tall-stemmed cycadeoid, Williamsonia, 4, Cycadeoidea, 5, a conifer, Araucarites Animals 6, a minute dinosaur, Compsognathus, only about 2 feet long, 7, a plant-feeding dinosaur, Camptosaurus, 8, a large carnivorous dinosaur, Allosaurus, 9, a plated dinosaur, Stegosaurus, 10, a giant sauropod dinosaur, Brontosaurus (length 65–70 feet), 11, a pterosaur, Rhamphorhynchus, 12, the first bird, Archaeopteryx*

the Early Mesozoic has been characterized as the *Age of Cycads* Although the cycadeoids have persisted until the end of the Mesozoic era, and are locally abundant in the Cretaceous rocks, they were eclipsed after Jurassic time by the great expansion of the modernized plants

*Yale Peabody Museum*

Fig 217. A living cycad

**Medieval Insects** About one thousand kinds of insects are known from the Jurassic rocks, and among these we note representatives of most of the modern orders Caddis-flies, scorpion-flies, dragonflies, and beetles were common, grasshoppers, cockroaches, and termites or white ants were also present, moths (Fig 219) and flies (Diptera) made their appearance at this time, and even the social ants were represented Since the last three groups represent the most highly specialized stocks of the insects, it is clear that the significant features of insect evolution had already appeared by the middle of the Mesozoic era

*Yale Peabody Museum*

Fig 218 Three-branched trunk of the cycadeoid, *Cycadeoidea marshiana*, from the Lower Cretaceous (Lakota sandstone), Cycad National Monument, Black Hills, South Dakota Courtesy of G R Wieland The specimen has an extreme width of about 25 inches

**Reptile Hordes.** By Jurassic time the *Age of Reptiles* was in full swing Not content with a complete domination of the lands, some of the reptiles anticipated the birds in flight, and others excelled the fishes in the sea The dinosaurs had attained their greatest size in ponderous sauropods so enormous that 60 to 75 individuals in circus parade would have spanned a mile Never before or since has the Earth been so completely under the sway of reptilian hordes

*Dinosaurs* were now in their heyday, and four of the five great tribes of these reptiles were represented Sauropods were the largest and

most distinctive *Brontosaurus* (Figs 216, 220), one of the best-known American forms, reached a length of about 65 feet, but the more slender *Diplodocus* had a length of nearly 80 feet, the brain of each of these huge animals, however, weighed less than a pound Until recently sauropods were almost unknown outside the Jurassic rocks, but now they have been found in the Lower Cretaceous of Wyoming, and in the Upper Cretaceous of New Mexico, Utah, and Texas

The plated dinosaur, *Stegosaurus* (Figs 216, 221), with a 2½-ounce brain for 10 tons of weight, was equally distinctive of this time In addition, there were bipedal carnivores of large and small size, one of which, *Compsognathus*, must have been as agile and slender as a small kangaroo, for it was only 2½ feet long Of the larger carnivores of this period, *Allosaurus* (Fig 216) was perhaps the greatest, having a length over all of more than 30 feet Still larger species lived in the Late Cretaceous
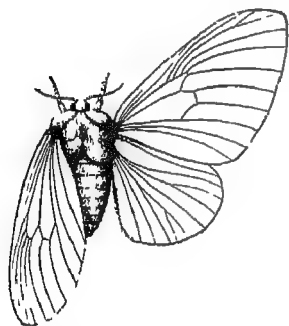
FIG 219 A Jurassic moth, *Limacodites mesozoicus*, as restored by A Handlirsch About 2/3 natural size

The herbivorous bipeds (ornithopods) are known from several genera but were less common here than in the Cretaceous

Among the most bizarre animals of the Mesozoic were the *pterosaurs* (Figs 20, 216, 222) or winged reptiles which "laid claim to the empire of the air in those medieval times " With leathern wings and naked bodies, they must have presented a batlike appearance, though the structure of their wings shows how superficial this resemblance was The bat is a warm-blooded animal allied to the other mammals, but the pterosaur was a reptile The bat has all its digits extended to bear the weblike wing membrane, whereas the pterosaur had only the fourth finger greatly extended to support the wing, leaving the other digits free to serve as claws The Jurassic species had sharp, slender teeth, and heads that were decidedly reptilian Some had long tails with flukes, which probably aided in keeping the balance during flight, but other forms were tail-less In the Jurassic pterosaurs the front and hind limbs were not greatly disproportionate in size, and it is clear that these winged dragons developed from quadrupedal land reptiles Upon alighting, they certainly walked on all fours (see Fig 222)

During the Jurassic period, the pterosaurs ranged in size from minute species with a wing spread equal to that of a sparrow up to

others that spanned 3 or 4 feet from tip to tip of wings. The greater and more highly specialized forms followed in the Cretaceous period.

In the seas, both *ichthyosaurs* and *plesiosaurs* were at the zenith of their development. The former, with their streamline contour and powerful fluked tail, must have been efficient swimmers (Fig. 223). They certainly resembled the modern porpoise to a remarkable degree, except that their tail flukes were in the vertical plane, so that they swam by a lateral instead of a vertical motion. The resemblance is purely superficial, however, for the porpoise is a warm-blooded animal and a mammal.

In the Lower Jurassic black shales of Germany, remarkably preserved specimens of ichthyosaurs are found with the entire skeletons articulated and surrounded by a carbonized film that outlines the con-

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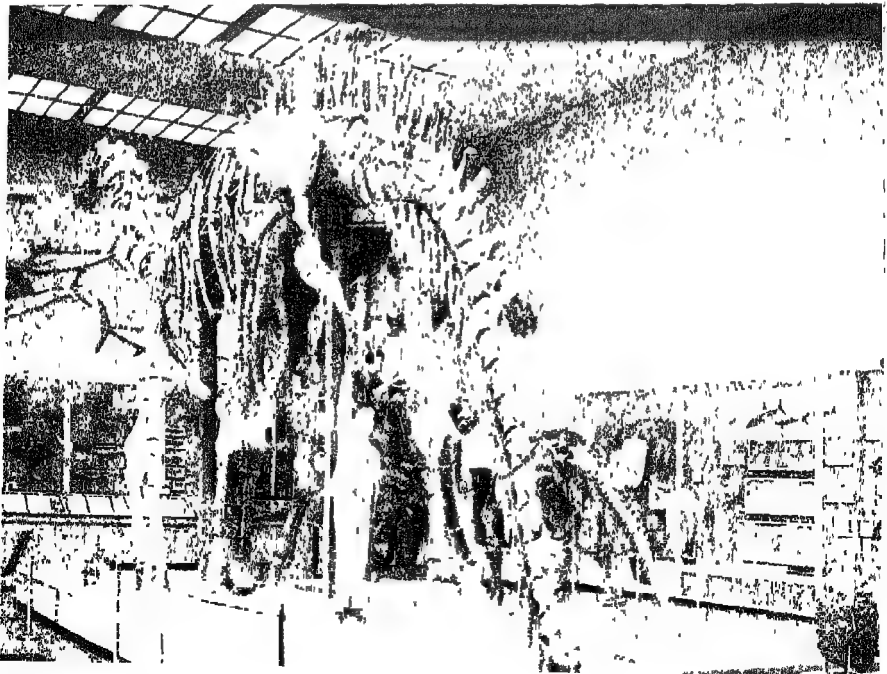
*Fig. 220. Skeleton of Brontosaurus. This specimen, from the Morrison formation at Como Bluffs, Wyoming, measures 67 feet from nose to tip of tail and stands about 18 feet high at the hips. A reconstruction may be seen in Fig. 216.*

tour of the flesh (Fig 18, p 38) Some of these, moreover, have been found with unborn young inside the rib case, proving that they were viviparous In this respect the ichthyosaurs show a more perfect adaptation to aquatic life than any other known reptiles, for even the great marine turtles come ashore to lay their eggs The Jurassic species were rather smaller than some of the Triassic forms, rarely attaining a length of 25 feet Many were mature at a length of 5 to 10 feet They fed on fish and cephalopods A remarkable skeleton found with some 200 belemnite shells inside suggests that they were especially fond of these squidlike animals

*Yale Peabody Museum*

Fig 221 Skeleton of the plated dinosaur, *Stegosaurus ungulatus*, from the Morrison formation at Como Bluffs, Wyoming

*Plesiosaurs* (Fig 224) are also best known from the Jurassic rocks In these reptiles the tail was not fluked, and propulsion was by means of the paddle-like flippers, as in the marine turtles The largest Jurassic species scarcely exceeded a length of 20 feet

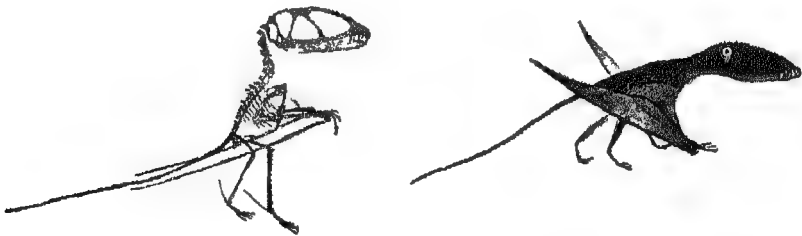



Fig 222 *Dimorphodon macronyx*, a small pterosaur from the Lower Jurassic in Lyme Regis, England Left, skeleton in bipedal attitude, right, flesh restoration in quadrupedal attitude The animal had an extreme length of slightly more than 3 feet From Seeley, *Dragons of the Air* (D Appleton and Company)

Slender-snouted *crocodiles* much like the modern gavial of India were abundant in the seas as well as in the rivers Marine *turtles* also were present, though less common than the groups of reptiles already mentioned

**First Birds.** Birds appear as fossils for the first time in Upper Jurassic rocks and represent one of the most remarkable advances that the life of this period has to show. As yet only three specimens are known, and these are from the famous lithographic stone quarries about Solenhofen, Bavaria. Two of these are fine skeletons with impressions of the feathers. The third specimen is the impression of a single feather. The two skeletons seem to represent different genera and species, though both are about alike in size and general features.

To the first-discovered bird was given the appropriate name *Archæopteryx* (Gr. *archaios*, ancient, + *pteron*, wing). It was a strange creature, more reptile than bird, and yet because of its feathers distinctly to be classed as a bird. It would be difficult to find a more perfect "connecting link" between two great groups of animals, or more cogent proof of the reptilian ancestry of the birds.

*Archæopteryx* (Figs. 216, 225) was about the size of a crow. Three remarkable features strike one at the first glance: (1) the jaws were set with a row of small teeth. These were not mere serrations on a horny beak but true conical teeth set in individual sockets like those of many reptiles. (2) In the wings the digits were not completely fused, and the first three still functioned as claws. (3) The tail was long and slender, with the feathers diverging pinnately from its axis and not fanwise as in modern birds. The plumage was thoroughly birdlike, but the teeth, clawed wings, and long tail betray reptilian affinities.

**First Mammals.** The most significant advance in the life of the Jurassic was the appearance of the primitive mammals (Fig. 226).

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*Fig. 223. The marine reptile, Ichthyosaurus, with a brood of young. From a painting by Charles R. Knight. The adult was about 10 feet long.*
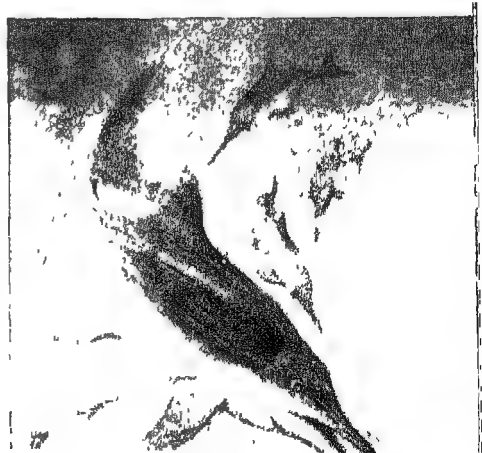
*Fig 224 The marine reptile, Plesiosaurus A pair of plesiosaurs in the foreground, with ichthyosaurs in the right background and fish in the left foreground After E Fraas, Stuttgart Museum*

Although small and unimpressive, they represent the early development of the warm-blooded animals which now dominate the Earth, and the group to which man himself belongs None of the Jurassic mammals was larger than a very small dog, and their known remains are quite fragmentary, consisting mostly of jaws, isolated teeth, and portions of limb bones Nevertheless, they are represented in North America, Europe, and Africa and probably ranged over all the continents except Australia Most of the fossil remains have been found in association with dinosaurs The American forms have all come from the late Jurassic (Morrison), and most of them from a famous dinosaur quarry at Como Bluffs, Wyoming The rest have been recovered mostly from Middle and Late Jurassic beds in England

In spite of their small size, these early mammals already showed marked specialization in their teeth, suggesting a wide variation in habits of life Among the Jurassic species, four orders can be recognized, all originating in theriodont reptiles All four of these early mammalian stocks are now extinct, but one of them (Pantotheria)

appears to have given rise during the Mesozoic to the modern marsupials and placentals, the others died out without descendants. Although, on theoretical grounds, the obscure little egg-laying mammals (monotremes) now living in Australia and Tasmania would seem to represent the most primitive possible stage of mammalian development, there seems to be no basis for the inference that the Jurassic mammals were also egg-laying. The monotremes may have developed independently of the other mammals out of ancient reptiles (Theriodontia).[5] Their geologic history is completely unknown.

**Marine Invertebrates.** The profusion of marine invertebrates and the richness of their fossil remains in the Jurassic rocks have already claimed our attention. In many respects these faunas were essentially modern. For example, *corals* of the modern families were then extensive reef makers, and abundant *pelecypods* (Pl. 14, figs. 6, 7) and *gastropods* resembled modern forms in general features. True *oysters* had already become common, though strongly plicate species were more prominent then than now. Lobsters and shrimplike *crustaceans* were present in numbers, and one depressed form (*Eryon*) foreshadows the evolution of the crabs (Fig. 227). The *crinoids*, locally abundant, resembled either of two modern types: the large stalked forms were closely allied to the *Pentacrinus* that still lives in deep water off the

*Fig. 225. The oldest known bird, Archæopteryx. Although here restored as feeding on fruit of the cycad, it was probably carnivorous. The bird was about the size of a crow. From the Upper Jurassic at Solenhofen, Germany. After G. Heilmann.*

Japanese coast, while small stemless species were like *Comatula* Sea-*urchins* of modern aspect were well represented (Pl 14, figs 1, 2), and among these were the first of the "heart-urchins," but there were no "sand dollars," the latter having evolved after the Cretaceous *Sponges* were in places important reef makers

More prolific and more distinctive than all other kinds of shellfish, however, were the *ammonites* (Pl 14, figs 9–11), which now attained the zenith of their career and were represented by a vast number of
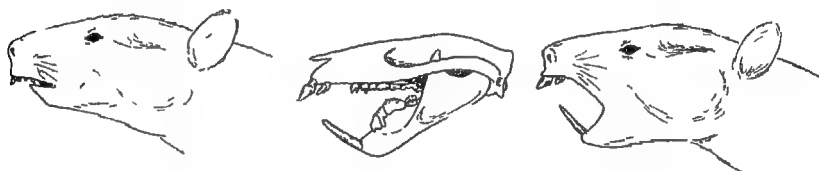
Fig 226 One of the best-known Jurassic mammals, *Ctenacodon*, from the dinosaur quarries in the Morrison formation at Como Bluffs, Wyoming It belongs to the extinct order Multituberculata The skull and two views of the head (about natural size) as restored by G G Simpson

kinds, some large and some small, but all possessing delicate pearly shells The intricacy and the variety displayed in the fluting of the ammonite septa during this period are remarkable, and the modification of bodily form of the living animals is an eloquent commentary on the plasticity of animal life Some species, with slender shells coiled like a rope and with the living chamber occupying more than an entire volution, must have had bodies of eel-like proportions, whereas others with broadly rounded, globular shells had bodies as short as the octopus The most remarkable of all modifications must have existed in those species with laterally compressed and deeply involute shells wherein the penultimate whorl of the shell was so deeply impressed in the animal's back as to divide it almost in two

The *belemnites,* some of them 5 or 6 feet long, were also at their climax at this time, and their cigar-shaped internal shells are extremely common fossils (Fig 228, and Pl 14, fig 8) Rare specimens found in the black shales of the Lower Jurassic in England and Germany show the form of the body and arms, preserved as a carbonized film about the shells From these it is certain that the belemnites were squid-like cephalopods with six instead of ten arms and with corneous hooks instead of sucking discs on the arms It is almost certain that true *squids* were also evolving from common ancestors
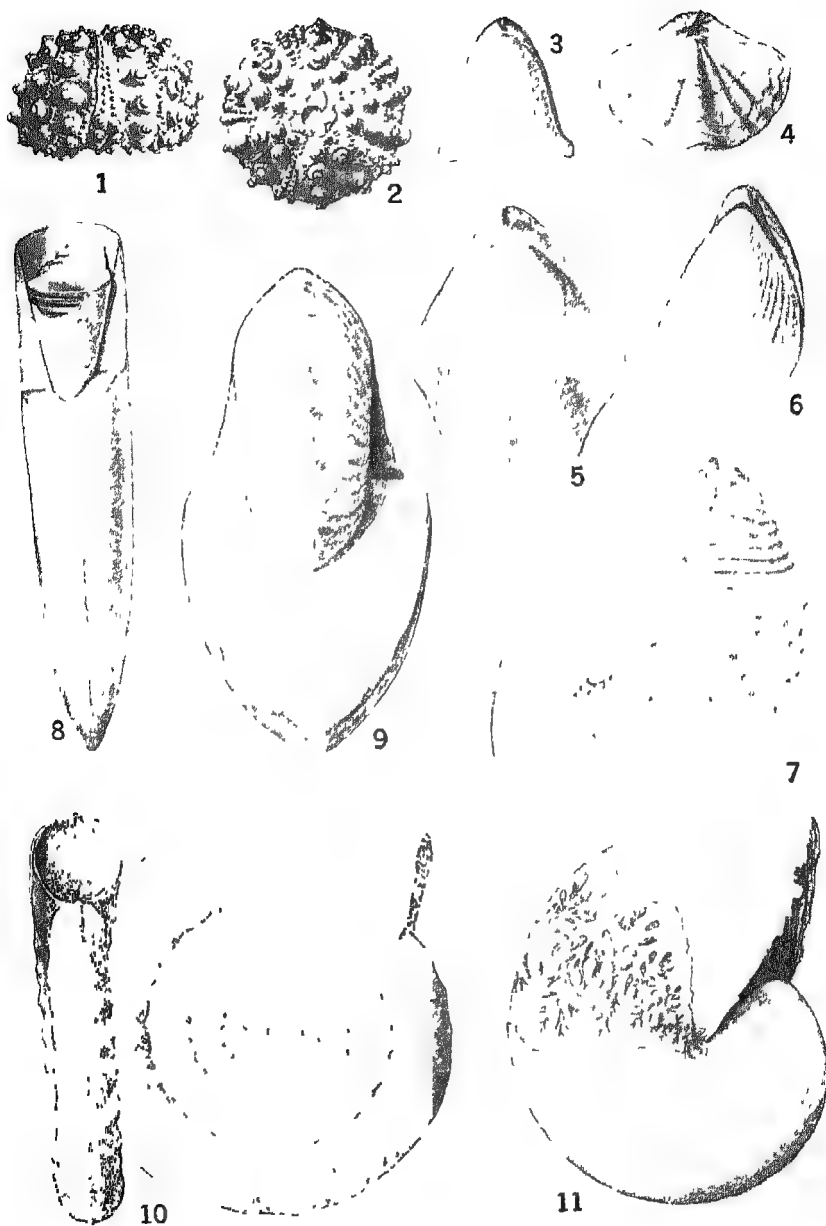
Plate 14  Jurassic Echinoids (1, 2), Brachiopods (3–5), Pelecypods (6, 7), and Cephalopods (8–11)

Figs 1, 2, *Hemicidaris intermedia* (side and upper views), 3, *Digonella digona*, 4, *Spiriferina walcotti*, last of the spiriferoids, 5, *Goniothyris phillipsi*, 6, *Aucella piochii*, 7, *Trigonia costata*, 8, *Belemnites densus* (broken to show chambered shell), 9, *Cardioceras cordiforme*, 10, *Echioceras raricostatoides*, 11, *Phylloceras heterophyllum*  All natural size  Drawn by L S Douglass

with the belemnites, but their shells were too perishable to have left an imposing record like that of the belemnites. It is interesting to note that an ink sac exactly like that of modern squids was present in the Jurassic forms and that the pigment is sufficiently preserved in some of the Lower Jurassic specimens mentioned above so that ink can still be made of it.

**Solenhofen, a Remarkable Fossil Locality.** In the region about Solenhofen, Bavaria, the Upper Jurassic rocks include circular reefs of sponges and corals within which there are deposits of very pure, fine-textured limestone. For generations this stone has been quarried and shipped to all parts of the world for the engraving of etchings and lithograph prints. During this time the quarries about Solenhofen and Eichstadt have yielded more remarkable fossils than any other locality in the world.
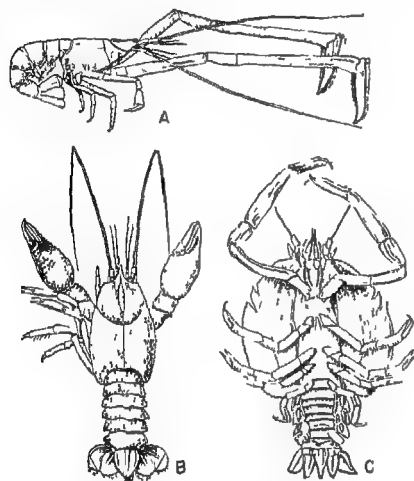
FIG. 227. Crustaceans from the Upper Jurassic limestones at Solenhofen, Bavaria. *A*, ghost-shrimp, *Mecochirus*; *B*, lobster, *Eryma*; *C*, a flattened, crablike form, *Eryon*. After A. Oppel.

The flawless, fine texture of the Solenhofen stone, so essential for the reproduction of the lights and shades in lithographs, lends itself equally well to the preservation of the delicate impressions of organic tissues. It has therefore given us a knowledge of many soft-tissued Jurassic animals, such as jellyfish, and has preserved impressions of the fleshy bodies of creatures otherwise known only from their skeletons or shells. From these quarries, for example, came all the known specimens of Jurassic birds. The faithful impression of their delicate feathers is a fortunate thing, for without this evidence it would be difficult to prove that *Archæopteryx* was not a reptile. Here also have been found specimens of pterosaurs in which the form of the delicate wing and tail membrane (Fig. 20) are preserved with remarkable fidelity. Among other things rarely preserved elsewhere are 8 kinds of jellyfish and more than 100 species of insects, including moths and flies. Finally, very good specimens of the horseshoe crabs (*Limulus*) occur here. A total of 450 species of animals has been recovered from these quarries.[6]

Evidently these are the deposits of lagoons within atolls that lay not far from the mainland The fossils include a dinosaur, 29 species of pterosaurs, and 3 birds On the other hand, there are no fresh-water animals, and marine fishes and marine invertebrates (mainly crustaceans and ammonites) comprise nearly all the fauna One remarkable feature of the deposit is that most of the organisms were not dismembered before burial There were certainly no scavengers living on the bottom, and the entombed creatures were either dead when

FIG 228 Reconstruction of a belemnite, darting backward and discharging a smoke screen of ink Such animals ranged from a few inches to 5 or 6 feet in length The internal shell of a belemnite is shown in Pl 14, fig 8

they were washed over into the lagoon or died soon thereafter and were quickly buried by the fine limy ooze that spread in from the fronts of the reefs It is because of this quick burial that the animals are so well preserved The floor of the lagoon may have been in part permanently submerged and in part only a mud flat covered twice daily by the tides

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*The Origin of Birds*, by G Heilmann 210 pages D Appleton and Co, New York, 1927

Includes an elaborate description of the toothed birds of the Jurassic and Cretaceous

*O C Marsh, Pioneer in Paleontology*, by Charles Schuchert and Clara Mae LeVene 541 pages Yale University Press, New Haven, 1940

Chapter VII has an account of the discovery of the great Jurassic dinosaurs in Colorado and Wyoming in 1877.

## Chapter 16

# CRETACEOUS TIME AND THE END OF AN ERA

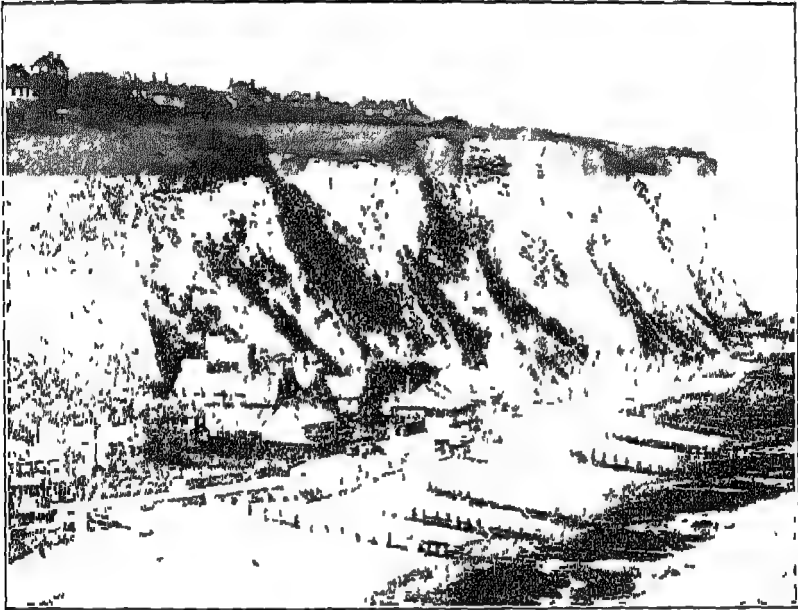
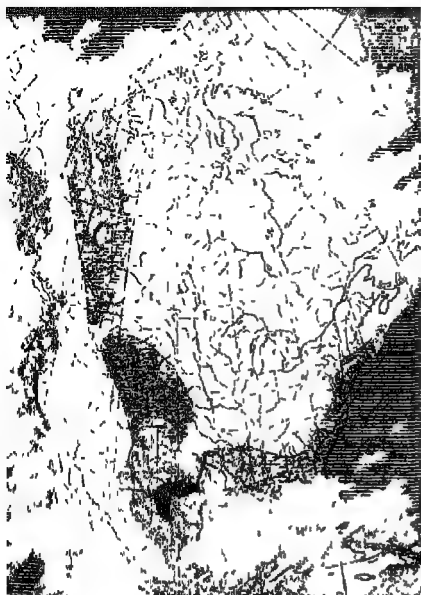
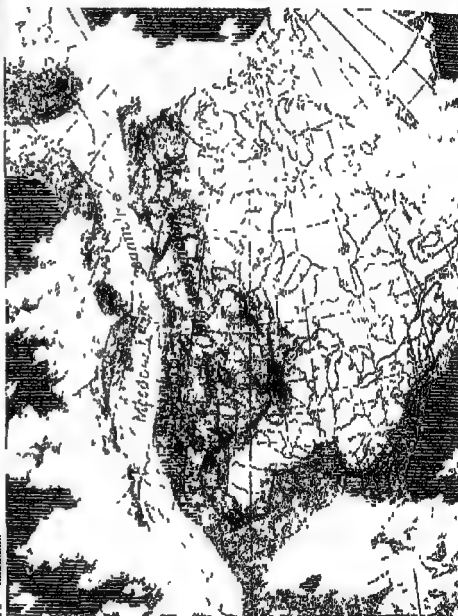
**General Features.** The name Cretaceous (Lat *creta*, chalk) was first applied to the extensive formations of chalk that form the white cliffs on both sides of the English Channel (Fig 229) Gradually the term was extended to embrace closely related strata of other kinds

Carl O Dunbar

Fig 229 Chalk cliffs at St Margaret on the Straits of Dover, England

until it included all the rocks between the Jurassic and the base of the Cenozoic The Cretaceous has thus become one of the greatest geologic systems, widely distributed in many countries and commonly very thick Considering the world as a whole, this was probably the age of greatest submergence of the continents and the most extensive epeiric seas the Earth has known.

It is remarkable that most of the chalk deposits of the Earth were formed during this single period, yet other types of sediments

laid down at this time vastly outbulk the chalk in most regions In this respect the term Cretaceous is a misnomer, but it has never had a rival since first proposed in 1822, and is now in universal use

During the present century there have been varied attempts to subdivide this great system into two, but no general agreement has been reached as to a natural line of separation In America, two subdivisions, Lower and Upper Cretaceous, are commonly recognized, however, the retreat of the sea from Kansas to southern Texas at the close of Early Cretaceous time may be interpreted as an incidental though marked oscillation in a great cycle of continental submergence Moreover, in southern Europe and in Mexico, a threefold instead of a twofold division seems more natural, and the planes of division do not accord very well with those in the United States In any event, the Early Cretaceous history may be looked upon as an introduction to that of the Late Cretaceous, and we shall here present the record as that of a single, long, and complex period

## Physical History of North America

### *The Last Great Submergence*

Early in Cretaceous time the sea began to spread over the continent, first from the Gulf of Mexico through the Mexican geosyncline into the southern United States, next from the Arctic into the Rocky Mountain trough, and finally across both the Pacific and Atlantic margins of the continent With an irregular and pulsing advance, the interior seas gradually united and submerged almost 50 per cent of North America, forming at their culmination one of the greatest marine floods of all time (Fig 230*B*) The climax came shortly before the middle of the Late Cretaceous epoch, and thereafter the interior sea retreated southward, was gradually silted up, and finally disappeared near the close of the period This was the last extensive submergence North America experienced, for in Cenozoic time the continent had its present outline and almost its present size.

**Atlantic and Gulf Overlap** Marine Cretaceous rocks, succeeding nonmarine beds, underlie the entire Coastal Plain from New Jersey to Texas, proving extensive submergence of the present coastal belt during the early part of Late Cretaceous time These marine formations overlap across the land, in many places passing into brackish-water or nonmarine beds in the landward direction, but grading into finer-grained marine strata toward the sea The sediments clearly

came from the present land mass and were spread eastward and southward over a shallow sea floor like the present shelf

Herein is a striking contrast with all the older marine deposits of eastern North America, for the latter had spread westward from the marginal land, Appalachia, into a geosyncline that lay within the continent Some time during the Jurassic, eastern Appalachia had foundered beneath the sea, and now, *for the first time in all the ages, the waves of the Atlantic were breaking against the margin of the present continent* During Early Cretaceous time the old land of Llanoria also continued to sink beneath sealevel, and the Gulf of Mexico, spreading across it, began to take form, though probably as a much shallower and far greater seaway than at present During Late Cretaceous time (Fig 230*B*) the head of the Gulf was at least as far north as Cairo, Illinois, that is, 600 miles farther north than today Its western shoreline lay in central Arkansas and Oklahoma, and its eastern margin encircled the southern end of the Appalachian folds in central Alabama and Georgia, probably inundating all of Florida Also, most of the larger Antillean islands, Central America, and Mexico were submerged

**Filling of the Rocky Mountain Geosyncline.** The broad Rocky Mountain trough was gradually submerged until it formed a vast seaway nearly 1000 miles wide and three times as long, completely dividing the continent into two land masses (Fig 230*B*) Its flooding records a long and gradual diastrophic cycle, for the slow submergence was followed shortly by a long emergence

The sea occupied the Mexican trough first, soon overlapping most of Texas It did not reach northward beyond Texas, however, until toward the end of Early Cretaceous time (Washita epoch), when a temporary pulsation sent it across Kansas, Nebraska, and Colorado into Iowa and Montana At about the same time the Arctic sea began to invade the northern end of the geosyncline A considerable retreat, following this advance, made a break in the sedimentary record in both the northern and southern sequences, and this fact has been used by some geologists as the basis for separating the Lower from the Upper Cretaceous as a distinct system The placing of so much emphasis on this break, however, has not been widely accepted, and we here retain the old view, regarding the Lower and Upper Cretaceous as of one period Soon after the middle of the period (Fig 230*B*) the southern and northern embayments met and flooded the entire region of the present Rockies and the Great Plains Even the granitic domes of the Colorado Mountains were submerged

in a sea that stretched from central Utah and southeastern Idaho to the plains of easternmost Minnesota and central Iowa

Soon after this maximum inundation the northern end of the geosyncline emerged, and the great epeiric sea began a southward retreat, hastened by the rapid filling of its basin with sediments which poured in, in ever-increasing volume, from rising highlands farther west The final retreat of the sea transformed its old floor into a vast swampy lowland over which the western streams spread thick nonmarine sediments during the closing stages of the period In the swamps of this lowland accumulated the vegetation that was to make the vast coal beds of the latest Cretaceous formations of the Rocky Mountains region from Alberta to Mexico

**Pacific Coast Overlap** West of the Rocky Mountain geosyncline lay the Mesocordilleran geanticline (Fig 230*B*) which had risen into mountains at the close of the Jurassic Still farther west there was a coastal belt involving much of the old Pacific Coast geosyncline of California and the western part of British Columbia Apparently, Cascadia was being submerged or had already subsided, and the Pacific shelf sea was spreading over the coastal belt from the peninsula of Lower California northward to Alaska This region in California was further broken by numerous north-south faults, and the unequal but rapid subsidence of some of the narrow fault blocks quickened the accumulation of very thick deposits of detrital sediments

### *Continued Rise of the Mesocordilleran Axis*

The Mesocordilleran geanticline was a rather narrow but rugged land mass throughout the period, shedding great quantities of detrital sediments both west and east At the beginning of the period it was a bold mountain chain, and the effects of later denudation were largely counteracted by repeated though irregular uplift, as the bordering geosyncline on the east deepened Much of this uplift may have been of the nature of gentle warping, but there is evidence of sharp uplift with some folding and marked volcanism in California about the close of the Early Cretaceous

The geanticline must have bristled with active volcanoes during much of the period, and especially during the last half, for there are many layers of *bentonite* (a rock made of altered volcanic ash) interbedded in the Cretaceous formations of the northern Great Plains which bear witness to heavy falls of volcanic dust that spread eastward as far as Nebraska and Kansas

*Laramide Revolution and the Birth of the Rockies*

Extended crustal unrest marked the closing stages of the Mesozoic era in many parts of the world, but nowhere with more profound and far-reaching effect than in the western half of North America At this time the floor of the great geosyncline, so recently covered by the Cretaceous sea, became the scene of folding and thrusting on a colossal scale, resulting in the Rocky Mountain system (Fig 230C) The orogenic belt stretched from Alaska to Mexico It involved a region fully 3000 miles long, and in the United States it had a maximum

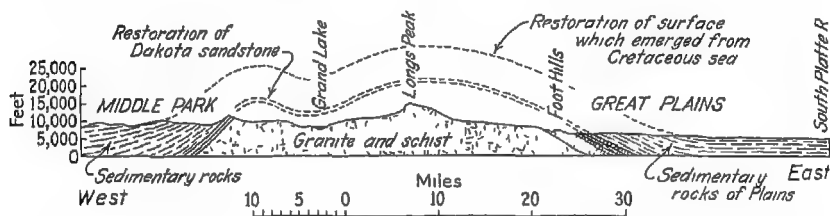



FIG 231 Section across the Front Range near Denver, showing its arched structure and suggesting the amount of erosion that has occurred since the uplift began After W T Lee, U S Geological Survey

width of 500 miles, extending from eastern Colorado to eastern Nevada and central Idaho It was clearly the most far-flung orogeny that North America had experienced since Pre-Cambrian time, and deserves to rank as one of the great revolutions It was long ago named the *Laramide revolution,* after the Laramie Range in Wyoming

**Nature and Extent of the Disturbance** Although the region has since suffered much erosion and has gone through a Late Cenozoic revolution, the Cretaceous structures are still as a rule clearly shown, and we can reconstruct the Late Cretaceous mountains in considerable detail

The orogenic forces at work brought about a great regional compression from the west The resultant structures differed greatly in diverse parts of the region, depending, undoubtedly, upon the nature and competency of the rocks involved, and, to some extent, upon the regional relation to the moving forces Figures 231 and 232 will aid in presenting the results of the orogeny (See also Fig 267, p 416 )

In the Southern Rockies the dominant structures were great open arches The Front Range in Colorado and southern Wyoming is one of these, and another, lying parallel to it on the west, is represented

by the Park and Sawatch ranges Between these lies a major synclinal fold still recognizable in the "Parks" (North, Middle, and South) of Colorado and in San Luis Valley Farther northeast in the Plains were formed the domelike arches of the Black Hills and the Big Horns West of the Colorado Rockies lay the great resistant mass of the Colorado Plateau, which remained almost undeformed Between it and the Front Range were one or more great thrust faults, the best known lying along the front of the Sawatch Range

The Middle and Northern Rockies were involved in thrust faulting of great magnitude The trace of the better known of these faults is shown in Fig. 232 The Lewis thrust along the front of the Montana Rockies is illustrated in Part I (p 467) Here the thick Proterozoic strata were driven eastward many miles over the Cretaceous rocks of the Plains, on a fault that has been traced for more than 50 miles north and south and may be continuous with a similar great thrust west of Great Falls, 100 miles to the south The east front of the Absaroka Range east of Yellowstone Park is defined by another fault, the Heart Mountain thrust, which is traceable for probably 125 to 150 miles and has an eastward displacement of at least 28 miles Greater still is the Bannock thrust of southeastern Idaho, which has been traced for 250 miles and has carried Cambrian and Ordovician rocks up over those of Pennsylvanian and Triassic ages

Fig 232 Trace of the major thrust faults produced by the Laramide revolution in the Cordilleran region After G R Mansfield, U S Geological Survey

in an eastward overthrust of at least 35 miles This is but one of several great thrusts in southeastern Idaho, and others are known in northern Utah and especially in southern Nevada, where a series of low-angle faults, dipping westward, involve the Jurassic and older rocks in a region where Cretaceous sediments were not present

West of this great belt of thrust faulting, the Cretaceous structures are now largely obscured by the Cenozoic formations in the Great Basin and the lavas of the Columbia River plateau The entire Pacific coastal belt was also uplifted enough to be completely emergent, for there is a great stratigraphic break between the Eocene and the Cretaceous in that region, but such deformation as there was must have been of the nature of regional upwarping or faulting, rather than folding Early in the Cenozoic those great structural troughs (remnants of the Pacific Coast geosyncline) now seen in the Gulf of California, the California trough, and Puget Sound began to take form as a result of normal faulting

Fig 233 Late Cretaceous batholiths The large area is the Idaho batholith, and the area south of Helena is the Boulder batholith Smaller intrusions are exposed about Butte

**Volcanism** Volcanoes were active intermittently on the old Mesocordilleran geanticline throughout the later Cretaceous, and toward the end of the period they spread farther east over the rising areas There is much volcanic agglomerate in some of the uppermost Cretaceous beds near Denver which must have come from volcanoes in Colorado In fact, it is probable that during the Laramide revolution every state west of the Great Plains had its active volcanoes

During the crustal movements granitic batholiths were intruded in several regions The most notable of these are the great *Idaho batholith* (Fig 233), whose eroded summit is now exposed over an area of 16,000 square miles in central Idaho, and the *Boulder batholith,* which underlies the region between Butte and Helena, Montana, and in which the great copper deposits of Butte were formed somewhat later

**Date of the Laramide Orogeny** It must not be supposed that a revolution so vast and complex was accomplished in a short time, even geologically speaking, or that the movements were strictly synchronous in all parts of the Cordilleran region Although the climax of the orogeny naturally determined the end of the Cretaceous period,

this was hardly a point in time but rather a phase in a great diastrophic cycle, and it came long after the uplift had begun. Meanwhile, the latest of the Cretaceous sediments were accumulating on the flanks of the rising mountains or in the intermont basins. Moreover, such great forces as those involved in the building of the Rockies were not all brought to rest at once.

As the moving forces accumulated, the sea floor buckled and local anticlinal folds arose as islands long before the sea had vanished. Evidence for this may be seen, for example, in southeastern Wyoming, where the Mesaverde formation of late (but not latest) Cretaceous age locally includes an erosion channel some 200 feet deep filled with sandstone and conglomerate, in which some of the boulders are of the Cloverly and Mowry formations that lie some thousands of feet lower in the section, and the Medicine Bow formation (very late Cretaceous) includes boulders of the Pre-Cambrian granite floor. These localities are almost in the center of the geosyncline, and since such coarse material could not have traveled far, it implies local uplift and deep erosion of the rising masses in the midst of the region of deposition.

In the critically studied Wasatch region to the northeast of Salt Lake City, eight stages of deformation have been recognized.[1] The first came at the close of the Jurassic or some time early in the Cretaceous and produced local highlands in western Utah. This is inferred from the character of the oldest Cretaceous formation of the Wasatch region, which begins with 700 feet of conglomerates. In these the boulders increase in coarseness and in abundance toward the west, and include fossiliferous pieces of Paleozoic formations that could only have been laid bare by uplift and deep erosion. This uplift may have been connected with the Nevadian rather than the Laramide disturbance.

A second and major disturbance, in the midst of Late Cretaceous time, resulted in east-west folds where the Uinta range later developed. Erosion of these folds truncated some 25,000 feet of beds which were unconformably covered by later Cretaceous deposits (the Henefer formation). This deposition continued to the end of the Cretaceous (possibly early Paleocene) and was followed by the climax of deformation that produced large-scale thrust faulting (Willard thrust). Sharp local folding occurred during Middle Paleocene time, and more gentle warping followed the Lower Eocene and was repeated in the Oligocene epoch.

Movement continued along some of the great thrust faults until long after the beginning of the Cenozoic, dying out in the Eocene or possibly in the early Oligocene. Just as the movements began earlier in some regions than in others, so also they continued longer in some of the ranges than in others. Likewise, the volcanism continued with irregularly decreasing vigor into the Cenozoic, and in many places it is not now possible, after extensive erosion, to distinguish clearly between Late Cretaceous and Early Cenozoic volcanics. The protracted nature of these orogenic movements still further complicates the difficult problem of fixing the boundary between the Mesozoic and Cenozoic rocks in the Cordilleran region. The problem is discussed on p. 375.

## Late Cretaceous Orogeny in Other Continents

During both the Paleozoic and Mesozoic there existed along the western side of South America a great Andean geosyncline, which received thick sediments from a wide and repeatedly rising borderland to the west. During the last half of Cretaceous time this geosyncline was folding and rising into a great mountain chain that was completed at the end of the Mesozoic. Beginning east of Trinidad, off Venezuela, these mountains extended southwestward into Colombia and thence southward to beyond Cape Horn, a distance of nearly 5000 miles. They were the South American counterpart of the Rocky Mountain system.

Standing athwart the course of the Rockies and the Andes is the Antillean mountain system of Central America, also formed at this time, following the trend of the Greater Antilles.

## Stratigraphy of the Cretaceous Rocks

### *Atlantic Coastal Plain*

Cretaceous formations underlie the Atlantic Coastal Plain from New Jersey southward and form a wide belt of outcrop where not overlapped by Cenozoic beds. They are mostly sands and clays, disposed in nearly flat-lying beds that dip very gently seaward. For the most part, they are only slightly indurated, the clays being soft and the sands loose and friable, but locally the sands are solid enough for building stone.

The entire system is less than 1000 feet thick in the outcrop belt, where it thins and laps out against the land It thickens down dip and probably reaches its full thickness some distance off shore, as shown by a well drilled in 1946 at Cape Hatteras, approximately 100 miles east of the Cretaceous outcrops This well reached the base of Cretaceous strata and penetrated granite at a depth of 9878 feet Both Lower and Upper Cretaceous formations are in the marine facies at this locality [2]

Lower Cretaceous formations are all nonmarine in outcrop, and exposures are practically limited to the Chesapeake Bay region and New Jersey The shoreline was clearly farther east than the present outcrop belt The Lower Cretaceous begins with basal sands that are coarse and gravelly, commonly arkosic, and generally cross-bedded Sands and clays alternate and also grade laterally one into another These features, along with the fossil land plants, crocodiles, and fragmentary dinosaur remains, indicate deposition by streams on a low coastal plain Dark, lignite-bearing clays record local swamps, whereas brightly colored and variegated clays, such as those extensively exposed about Baltimore, were deposited on well-drained parts of the landscape

Upper Cretaceous formations overlap and largely conceal the Lower Cretaceous south of Chesapeake Bay and form a wide belt of outcrop along the inner margin of the Coastal Plain most of the way from New Jersey to Georgia They resemble the Lower Cretaceous formations in being detrital and relatively unconsolidated, but are for the most part marine The higher formations include extensive deposits of "greensand marl," which is composed of sandlike granules of glauconite, a silicate mineral rich in potassium and iron Before the discovery of rich potash salt deposits in the Permian of Germany, the New Jersey greensand was extensively quarried for the extraction of potassium used in the manufacture of fertilizer Curiously, greensand, like chalk, is more abundant in Cretaceous rocks than in any other system, though by no means confined to them The greatest deposits are in New Jersey, but much glauconite occurs farther south, even in the Gulf Coastal Plain In the Lower Cretaceous of western Europe, also, glauconite is so common that a considerable series of these strata is commonly known as "The Greensand"

### *Eastern Gulf Region*

From Georgia to northern Mississippi and western Kentucky the Upper Cretaceous overlaps on the Paleozoic and older rocks, covering

the Lower Cretaceous formations completely Here the Upper Cretaceous attains a thickness of 2000 feet or more (Fig 234) Although it begins with nonmarine sands (Tuscaloosa formation), it is largely a marine deposit, and in eastern Mississippi and western Alabama the upper 1000 feet is a soft, argillaceous limestone known as the "rotten limestone" or the *Selma chalk* (Fig 235). Eastward, in Georgia, the limestone changes into shale and sands, and to the westward the "chalk" also becomes more muddy and grades over into a thick ma-

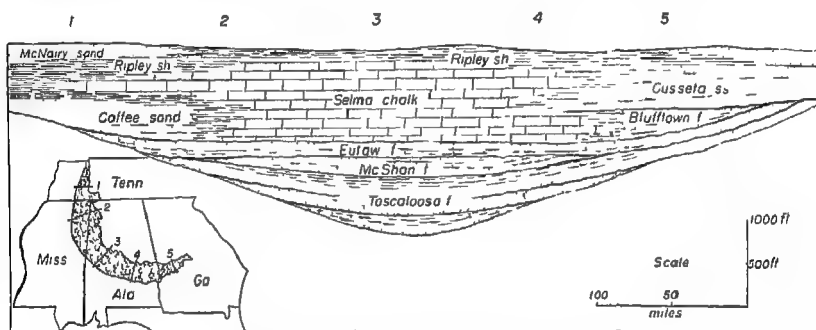



FIG 234 Cross-section of the Upper Cretaceous formations of the eastern Gulf Coastal Plain, showing facies changes along the strike As indicated by the inset, the section runs nearly south from western Tennessee to east-central Mississippi and then swings eastward to central Georgia The central part was deposited farther from the Cretaceous shoreline than either end, and deposition began there first Vertical scale greatly exaggerated Adapted from L W Stephenson and from Watson H Monroe, U S Geological Survey

rine shale known as the *Ripley* (Fig 236) Still more to the west and north, tongues of sand interfinger into the shale, and the formation grades laterally into the *McNairy sandstone,* which in places bears abundant fossil land plants

In short, three types of sediment were forming simultaneously in the eastern Gulf region during later Cretaceous time (1) sands and silt in western Tennessee and Kentucky (also in Arkansas), (2) silt and mud in northern Mississippi, and (3) calcareous mud farther south and east Here is a parallel to modern conditions, wherein sand and mud are being laid down on the floor of the Gulf near the mouth of the Mississippi River, while fine mud spreads farther east and limestone is forming in the clear shallow waters about Florida The McNairy sandstone represents part of a Cretaceous delta formed by streams foreshadowing the present Mississippi River system, and, since the sands spread more and more widely as we ascend in the

series, we may infer that the delta was growing southward toward the close of the period

All of Florida now has Cenozoic strata at the surface, but deep wells indicate the presence of Upper Cretaceous formations resting on very ancient rocks A recent deep well in western Florida (Jackson County) went through more than 4000 feet of Upper Cretaceous strata, and another, 50 miles west of Miami, near the southern tip of Florida, penetrated 2276 feet of Upper Cretaceous and 1900 feet of probable Lower Cretaceous, stopping in supposed Lower Cretaceous at a depth of 10,006 feet

*Western Gulf Border and the Cordilleran Region*

**Comanche Series** The Mexican sea gradually extended northward across Texas, depositing marine formations far and wide over the western Gulf border and in the Rocky Mountain trough The Lower Cretaceous has a grand development in Texas and Mexico, with 4000 feet of richly fossiliferous limestones and marls in the latter country and about 1500 feet in southern Texas These formations constitute the Comanche series, so named for the many outcrops in the ancestral home of the Comanche Indians Nearly one-half of the vast domain of Texas is covered with either Lower or Upper Cretaceous forma-

L W STEPHENSON, U S GEOLOGICAL SURVEY

*Fig 235 Typical exposure of the Selma chalk, Jones Bluff, Tombigbee River, Alabama*

tions, and the marine record is here the most complete in the United States More than half of the mineral wealth of Texas (largely petroleum) is now produced from these rocks

The Comanche formations are almost entirely limestone in eastern and central Mexico, but in Texas and Arkansas they grade over into a near-shore facies of calcareous shale, sandstone, and thin-bedded

*Carl O Dunbar*

FIG 236 Outcrop of Ripley shale showing a shell "bank" made by *Gryphæa convexa*, a relative of the oyster Near Corinth, Mississippi

limestone Only the uppermost beds were involved in the overlap across Kansas and Iowa, and there they are shales and sandstones, fluvial in part It is significant also that detrital sediments thin out gradually in their overlap on the old lowland toward the north, whereas in southeastern Arizona (at Bisbee) they thicken to 4700 feet and include thick conglomerates and much sandstone

The influence of the Mesocordilleran highland is evident here as well as in northwestern Mexico, where the Comanche formations are thick (3000 feet in northeastern Sonora), detrital, and coal-bearing

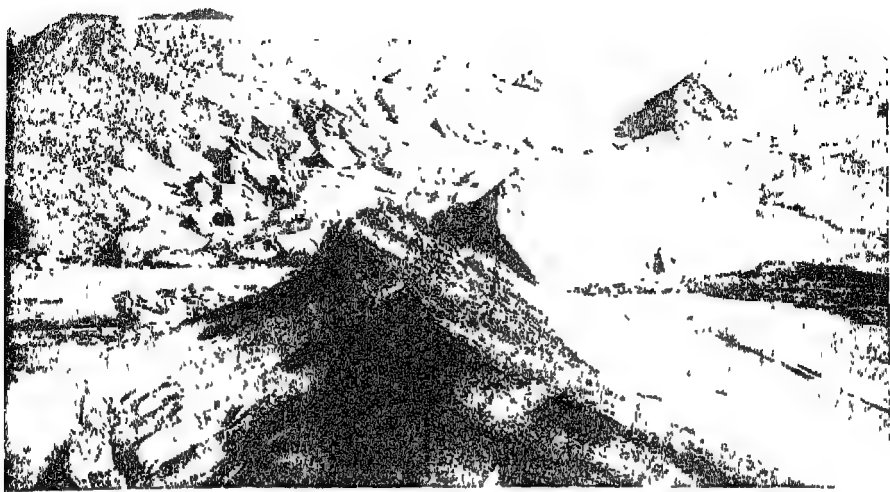
There is another notable Lower Cretaceous development in the Rocky Mountain trough of Canada The seaway responsible for these beds was an extension from the Arctic which began to invade Canada

T S LOVERING AND F M VAN TUYL, U S GEOLOGICAL SURVEY

*Fig 237 East flank of the Front Range near Denver, showing hogbacks of Cretaceous and older strata upарched by the Laramide revolution An aerial view looking north, from an altitude of 7100 feet The great hogback in the foreground is formed of Dakota sandstone, and those in the middle distance at the left are of Pennsylvanian (Fountain) sandstone The mountains at the left are of Pre-Cambrian granite Longs Peak is at the horizon just left of the center of the view*

in the middle of Early Cretaceous time, and finally, early in the Late Cretaceous, united with the transgressing waters from Mexico In southern Alberta the Lower Cretaceous formations are largely of fresh-water origin (Kootenai and Blairmore), but those of the Upper Cretaceous are largely marine

**Upper Cretaceous Series** The Upper Cretaceous formations underlie all the Great Plains and much of the Rocky Mountain region, generally exceeding 2000 feet in thickness in the east and attaining a maximum in western Wyoming of about 20,000 feet Their stratigraphic relations are complicated by the facts that the sediments were coming largely from the western highlands, and that from time to time vast deltas or alluvial coastal plains were developed along this side of the trough, while finer-grained marine sediments were accumulating farther east across the geosyncline This resulted in an interfingering into the marine section of great wedges of continental deposits from the west, bearing the remains of land

plants, coal beds, and dinosaurs (Figs 238, 239) Hence the lithologic characters and the divisions recognized in one area do not agree with those of another, and only the larger groupings can be presented here In general, however, four great divisions are recognizable, the Dakota sandstone, the Colorado group, the Montana group, and the Laramie group

The *Dakota sandstone* is the basal member of the Upper Cretaceous over a very large area Although generally between 100 and 400 feet thick, it persists under most of the Great Plains and outcrops in strong

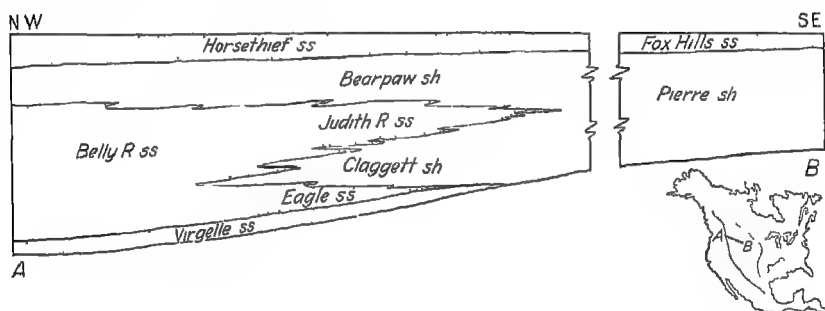



FIG 238 Idealized cross-section of the Montana group of the Upper Cretaceous system, from southern Alberta (*A*) to the Black Hills of South Dakota (*B*), showing the interfingering of the marine shales (*unshaded*) with tongues of sandstone (*stippled*) from the west The Virgelle, Horsethief, and Fox Hills sandstones are shallow-water marine deposits, but the Belly River-Judith River beds are floodplain and delta deposits, bearing land plants and dinosaurs Length of section 700 miles, a considerable length of the middle part being deleted Adapted from E Stebinger, U S Geological Survey

hogbacks (Fig 237) along the front of the Rockies and about the Black Hills It is the chief horizon for artesian water in the eastern Great Plains and is one of the greatest water reservoirs known The Dakota sands are rusty, irregularly bedded, and generally cross-laminated, they include much silty shale and grade laterally from thick sand beds to shale in an irregular fashion No marine fossils are present, but leaves of land plants are locally abundant The formation was evidently spread over the floor of the geosyncline by aggrading streams in advance of the seas that were transgressing from both the south and the north

The *Colorado group* (Figs 230*B*, 239) includes fine-grained marine strata under the Great Plains, the lower part being dark gray shales (*Benton*) and the upper part a soft argillaceous limestone known as the *Niobrara chalk* The chalk is of interest as the source of many striking vertebrate fossils, notably the large diving birds, the great

marine reptiles and fishes, and the greatest of all pterosaurs Traced westward through Colorado and New Mexico, the limestone passes into shale, which in many places becomes sandy Finally, in the Black Mesa coal fields of northeastern Arizona, the upper half of the group has gone over into massive cliff-forming sandstones with important coal beds

The *Montana group* is rather simple in the central and eastern Great Plains, where it consists of a thick but very fine-grained marine shale (*Pierre*), capped by a shallow-water marine sandstone (*Fox Hills*) Northwestward, however, the marine shale is divided by

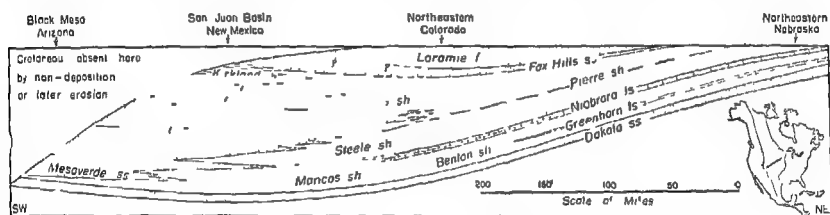



Fig 239 Restored section of the Upper Cretaceous formations of the Rocky Mountain geosyncline, showing the intertonguing of thick nonmarine sandstones from the west (*stippled*) into the marine deposits Vertical scale greatly exaggerated

wedges of nonmarine sandstone and shale that thicken steadily toward the old shoreline at the expense of the marine shales These are dinosaur- and coal-bearing deposits, representing deltas or coastal plains formed in front of the rising land mass of the Mesocordilleran geanticline (Fig 238)

The *Laramie group* includes several thousand feet of nonmarine coarse detritals spread over the floor of the geosyncline by aggrading streams after the sea had withdrawn It was named for the Laramie basin in Wyoming, where it is very thick, as it likewise is in the Denver basin of Colorado, the Big Horn basin of Wyoming, and the western part of the plains of Wyoming and Dakota, but it thins gradually toward the east in the Dakotas There is also a large area of these deposits in the plains of Alberta

Fossil land plants are abundant, and the last of the dinosaurs are represented by many fine skeletons, but no marine fossils are present

The Laramie group has given rise to one of the two most prolonged controversies in the history of American geology The land plants are remarkably modern in their aspect and were believed by the early paleobotanists to be of Cenozoic age The dinosaurs, on the contrary, are clearly allied with Cretaceous types and are quite unknown any-

where in undoubted Cenozoic rocks. Not a bone of any dinosaur has been found in the overlying Fort Union formation. Accordingly, some paleobotanists wished to draw the Mesozoic-Cenozoic boundary line *below* the Laramie, and the vertebrate paleontologists placed it *above* (some, even above the Fort Union). As the controversy became more acute, structural evidence was sought, but unfortunately, in the area where fossil vertebrates are common, no clear angular discordance is known between the youngest undoubted Cretaceous beds and those that are clearly Cenozoic. Erosional unconformities were found both below and above the Laramie (and in the Fort Union as well) in various localities, but such unconformities occur at many horizons in the nonmarine beds of the region, and the time significance of any particular one is problematical.

Closely allied in nature to the Laramie, and overlying it, is the Fort Union formation of fluvial sandstones and shales with abundant land plants, many mammal bones, and coals. Its plants have close affinities with those of the Laramie, but it has not a trace of a dinosaur. Restudy of the fossil plants of both Laramie and Fort Union strata has recently proved that they are really quite distinct, much of the older confusion having resulted from the mixing of Fort Union and Laramie collections because the stratigraphic boundary was not correctly understood.[3] The evidence of fossil plants therefore now agrees with that of the vertebrates as to the Cretaceous-Cenozoic boundary.

Beds identified as Fort Union strata in the Big Horn basin have recently yielded four distinct zones of mammalian fossils which show a definite correlation with the oldest Cenozoic (Paleocene) formations. The details are presented in Chapter 17.

### *California and British Columbia*

As portions of California subsided after the Nevadian disturbance at the close of the Jurassic, coarse detrital sediments from the mountains poured into the basins and accumulated rapidly and to great depths. The Lower Cretaceous strata, known as the *Horsetown formation*, commonly reach a thickness of 10,000 feet and at a maximum exceed 26,000 feet along the west side of the Sacramento Valley in California. Recently the volume of the detrital Cretaceous deposits (mostly Lower Cretaceous) in that valley has been estimated at 13,400 cubic miles. Fossils are sparse, and the material is partly of brackish- or fresh-water deposition, but marine fossils are scattered through the section and five distinct faunal zones prove that all the major divisions of Lower Cretaceous time are represented.

The early half of the Late Cretaceous is represented in California by the *Chico formation* of sandstones, shales, and conglomerates, having a thickness of several thousands of feet The same formation is thick and coarse all along the coastal belt of British Columbia from Alaska to Vancouver Island, measuring 5000 feet thick at the latter place and 11,000 feet in the Queen Charlotte Islands, where there is much volcanic material

FIG 240 Cretaceous and early Cenozoic coal fields of the Rocky Mountain region After M R Campbell, U S Geological Survey

### MINERAL RESOURCES

**Coal** In the Late Cretaceous and Early Cenozoic (Fort Union) rocks of the Rocky Mountain region, there are more than 100,000 square miles of coal-bearing lands (Fig 240) These fields have an estimated reserve of almost 900,000,000,000 tons in beds more than a foot thick and within 3000 feet of the surface However, most of this coal is of low rank (either bituminous or sub-bituminous) and does not now compete to any considerable extent with the older coals outside the Rocky Mountain region Locally, where the metamorphism is severe or where igneous rocks have invaded the Coal Measures, as in the Crested Butte field of central Colorado, anthracite is mined

This coal varies in age from field to field In the Black Mesa field of northeastern Arizona it is in the basal part of the Upper Cretaceous, but by far the greatest part is in the Laramie group at the top of the Cretaceous and in the Fort Union at the base of the Cenozoic Considering the region as a whole, the Fort Union is probably the greatest coal-bearing horizon In the Anthracite-Crested Butte fields of Colorado, the coal is of Laramie age

Colorado is now the leading coal producer among the western states, but Wyoming appears to have far greater reserves In the Crowsnest

Pass region of Alberta, there are extensive coals in the Lower Cretaceous (Kootenai) strata, and where these rocks have been severely folded it is estimated that some 400,000,000 tons of the coal are anthracite

**Petroleum** Cretaceous rocks have been an important source of oil and gas in several parts of America They are the chief horizon of the Mexican oil fields and for many years kept that country in the forefront as one of the three greatest oil producers in the world Phenomenal gushers like Cerro Azul No 4 in the Huasteca field, which jetted 1,000,000 barrels during its first week of flow, seem to have derived their oil from caverns in the Lower or Middle Cretaceous limestones Venezuela has also produced much oil from the Cretaceous, and Argentina a smaller amount In the United States, Cretaceous production supplies the great Salt Creek field of Wyoming and many others in that state, Montana, and Colorado The richest of all the North American fields was brought in during 1930 in the Cretaceous rocks of eastern Texas, where an old beach deposit of the overlapping Upper Cretaceous was found to be saturated with oil over an area 4½ miles wide and 38 miles long The extraordinary yield from this area led to the overproduction of 1931–1932, which was followed by enforced curtailment of the oil output in Oklahoma and Texas

**Gold, Silver, and Other Metals** Metalliferous deposits were formed widely throughout the Rocky Mountain region as a by-product of the igneous activity that accompanied the Laramide revolution The copper, zinc, and silver veins of Butte, Montana, the most richly mineralized district in the world, were formed at this time Mineralization has recurred at different epochs in different mining regions during the late Cenozoic, so that it is impossible at present to generalize and say how much of the mineral wealth of America should be attributed to the late Cretaceous events, but the gross value must be very great

## Climate

The general temperature seems to have fallen somewhat after the Nevadian disturbance, for reef corals were more restricted in the Early Cretaceous than they had been in the Jurassic Moreover, in the middle part of the Early Cretaceous (Aptian time) the highland plateau of eastern Australia appears to have been ice-capped, with glaciers flowing westward into the sea In any event, icebergs dropped into the interior sea well-striated stones in sizes ranging up to 6 feet

across, and these erratics are known through some 600 miles of outcrops.[4]

With the greater spread of the seas in early Late Cretaceous time, the climate gradually became mild and equable over most of the land surface of the Earth, especially during the latter part of the period. Upper Cretaceous rocks preserve, even in high latitudes, abundant remains of land plants belonging to genera now restricted to warm-temperate or subtropical regions. In central-western Greenland, for example, the Cretaceous beds contain figs, breadfruits, cinnamons, laurels, and tree ferns, and in Alaska they have yielded cycads, palms, and figs. Although most of these are commonly thought of as strictly tropical trees, each of the genera has representatives in the temperate zone, and it is not necessary to conclude, as some have done, that tropical climate extended into polar latitudes. Nevertheless, there is sufficient evidence for maintaining that Greenland was without an ice cap and that the climate there was then temperate rather than frigid.

The abundance of the great dinosaurs in Alberta and Mongolia during part of the Cretaceous seems to imply a very mild temperate climate at least that far north.

There was apparently a marked drop in the temperature of western North America after the Laramide revolution, however, for extensive mountain glaciers existed in the San Juan Mountains of southwestern Colorado in early Cenozoic time. This may have been an important factor in the extermination of the dinosaurs and other characteristic groups of Cretaceous land animals.

## Life of Cretaceous Time

### *Spread of Modern Plants*

*Deciduous trees* suddenly became conspicuous in the Early Cretaceous, and long before the close of the period dominated the landscape in all the continents, just as they do today. Among the oldest of these were the magnolia, fig, sassafras, and poplar, all of which appear in the middle Lower Cretaceous deposits. By the middle of the period the forests were essentially modern, including such trees as beeches, birches, maples, oaks, walnuts, planes, tulip trees, sweet gums, breadfruit, and ebony, along with shrubs like the laurel, ivy, hazelnut, and holly (Fig. 241).

With these, of course, there were evergreens, just as now, but they no longer dominated the landscapes as they had done during the earlier Mesozoic Among the conifers a conspicuous type was the sequoia,

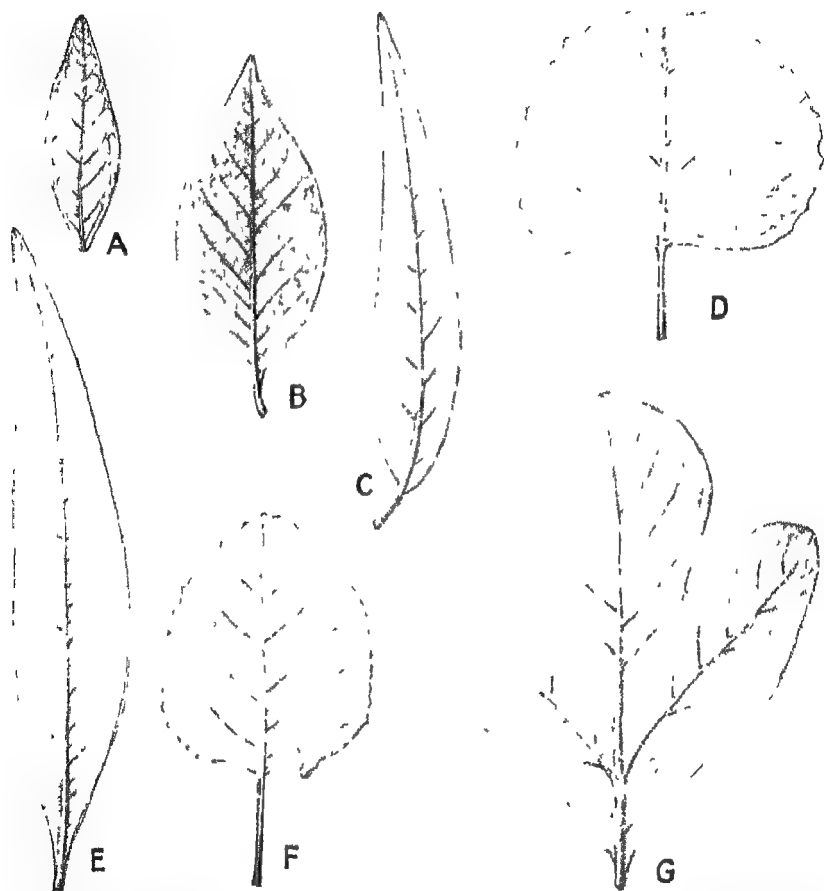



Fig 241 Cretaceous plants *A*, *Andromeda snowi*, a relative of the rhododendrons, *B*, *Magnolia pseudoacuminata*, *C*, *Salix lesquereuxi*, a willow, *D*, *Populites elegans*, *E*, *Ficus lanceolata-acuminata*, a fig, *F*, *Betulites westi latifolius*, a birch, *G*, *Sassafras parvifolium*, a sassafras After E W Berry and L F Ward

although none are known so large as the modern giants of California, it is interesting to note that the race was widely distributed over the northern hemisphere at this time

Most deciduous trees belong to the *angiosperms*, the highest order of the plant kingdom and the one that includes all the true flowering

plants (exceptions are certain gymnosperms, such as the gingko and the larches) Besides the hardwood trees mentioned above, this order includes the grasses and cereals as well as the seed- and fruit-bearing shrubs, annuals, and our common vegetables The strong deployment of this group of plants in the Cretaceous was one of the most significant advances in the whole evolution of plant life, second only to the spread of plants over the lands On their own account, this was an important milestone in the history of life, for the angiosperms are the most highly specialized of all plants and the ones destined to dominate the Earth during later geologic time In addition, their indirect effect upon the advances of the higher animals can hardly be exaggerated, for they supply nearly all the plant food for the mammals that now dominate all other life upon the Earth Angiosperms provide the nuts and fruits of the forest, the grasses of the prairies, the cereals which furnish fodder and grain for man and his domestic animals, and all the vegetables and fruits that man has cultivated, to say nothing of the flowers that add so much pleasure and inspiration to human surroundings It would hardly be too much to say that the great expansion of the mammals and the birds had to wait upon the evolution of the flowering plants, it was certainly no accident that in the next period the reptilian hordes gave way to a spectacular rise of warm-blooded vertebrates

The oldest known angiosperms appear almost simultaneously in New Zealand, in Texas, and in the coastal plain of Maryland Of these the best-known occurrence was described from the Paluxy sand of the basal Cretaceous Trinity group in Erath County, central Texas [5] Three types of deciduous tree leaves were found, one of which is a species of cinnamon From middle Lower Cretaceous rocks angiosperms are known in Portugal and Maryland The oldest Cretaceous formation of the Atlantic Coastal Plain (Patuxent) has yielded none of these modern plants, though it has plenty of evergreens like the Jurassic floras In the middle member (Arundel) of the Lower Cretaceous of Maryland, however, several species of deciduous trees are represented Before the middle of the period they had spread over the Rocky Mountain region, and they comprise more than 90 per cent of the known plants of the Upper Cretaceous

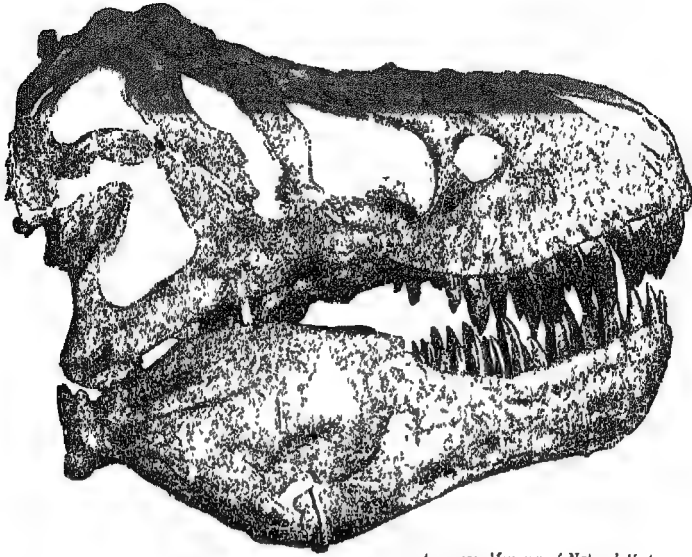
The resting stage represented by the ripening of the seeds and the shedding of the foliage of angiosperms is clearly an adaptation to seasonal and rigorous climates, either of winter cold or of drought. Probably the evolution of these plants out of the older types took place on the highlands where the climate was cool and growth was

*American Museum of Natural History*

Fig 242 Skull of *Tyrannosaurus rex*, the greatest known carnivorous dinosaur Length of original, 4 feet, 3 inches

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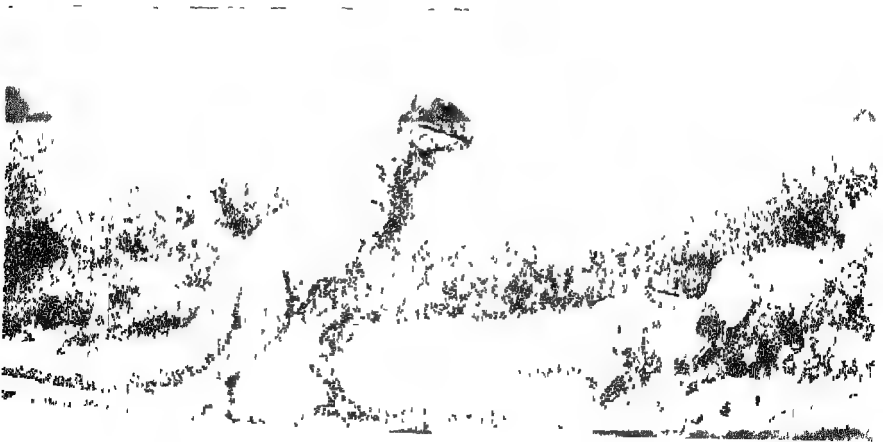
*Fig 243 Tyrannosaurus rex and Triceratops horridus, from a painting by C R Knight Based on specimens from Hell Creek basin, Montana*

seasonal, but, if so, it was not until they had migrated into the lowlands where sedimentary deposits were forming that they left a record of their existence It is quite possible, therefore, that they were actually present in Jurassic or Triassic time even though our oldest record is in Cretaceous rocks

*Culmination of Reptilian Evolution*

**Dinosaurs** held the center of the stage until the last scene of the Mesozoic drama (Frontispiece) The great sauropods persisted locally where the environment was suitable, as proved by recent finds in the Lower Cretaceous of Wyoming and in the Upper Cretaceous of New Mexico, Utah, and Texas They are known also from very fragmentary remains in the Cretaceous rocks of Maryland and South America *Stegosaurus* was extinct, but its race persisted in heavily plated types like *Palæoscincus* The two great races of bipeds, however, were at their climax The carnivores varied much in size Among them stalked *Tyrannosaurus rex,* the mightiest flesh-eater ever

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*Fig 244 The duck-billed dinosaur, Trachodon mirabilis, from Converse County, Wyoming Painted by Charles R Knight Such animals were about 25 feet long from nose to tip of tail*

present upon the lands, carrying his ponderous head 20 feet from the ground and spanning about 45 feet from nose to tip of tail (Frontispiece, Figs 242, 243) In striking contrast with this "king tyrant saurian" there were other carnivores of small stature (*Ornithomimus*) which had no teeth but only a horny beak much resembling that of an

*C W Gilmore, U S National Museum*

FIG 245 Portion of the tail of a late Cretaceous bipedal dinosaur, *Corythosaurus*, with part of the skin preserved Red Deer River Valley, Alberta

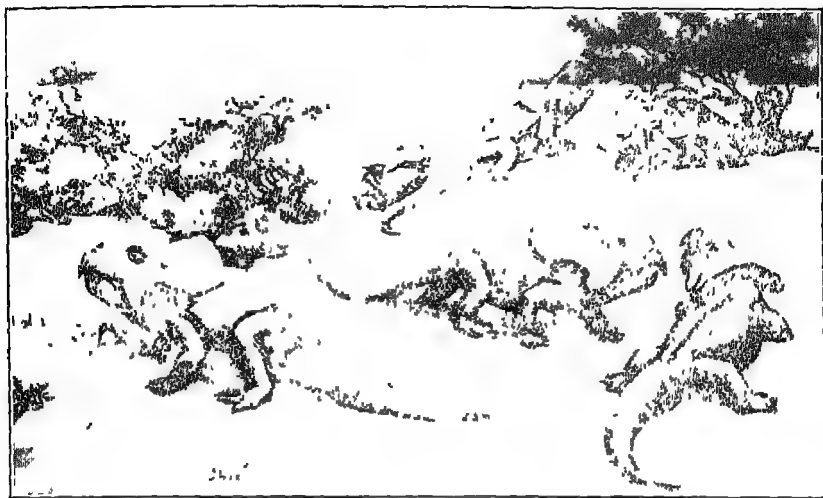
ostrich They probably fed like an ostrich and therefore were not truly carnivorous, though descended from flesh-eating ancestors The herbivorous bipeds were well represented by the "duckbills" in Late Cretaceous time (Figs 244, 245) Besides these, a fifth great tribe, the *Ceratopsia* or horned dinosaurs (Frontispiece, Figs 243, 246), now made their appearance The only occurrence of ceratopsians outside of North America is that of *Protoceratops* in Mongolia, where skeletons representing all stages of growth have been found, with several nests of eggs (Figs 246, 247) This was a small form with a height of only 3 or 4 feet In the Late Cretaceous some of the American Ceratopsia were 20 feet long and more than twice as bulky as the

*Chicago Natural History Museum*

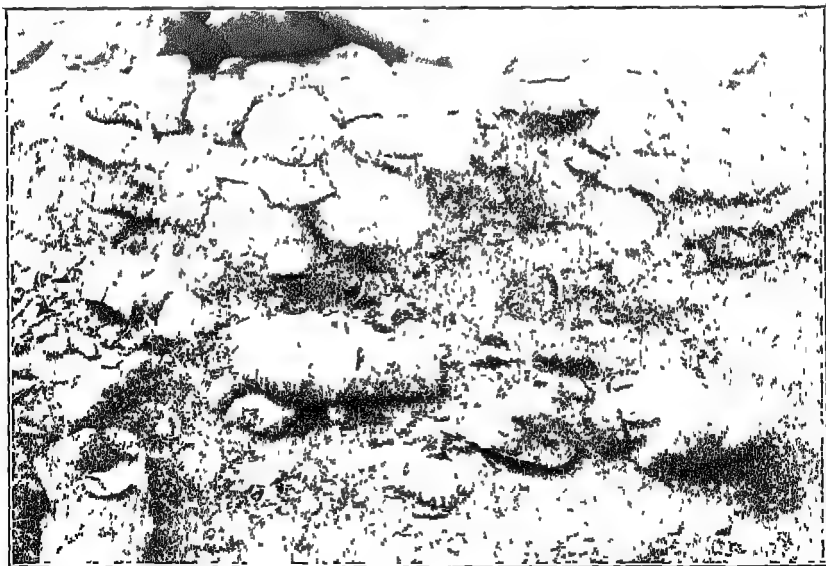
FIG 246 The primitive horned dinosaur, *Protoceratops*, with nest of eggs Painting by Charles R Knight, based upon skeletons and nests from the Gobi Desert of Mongolia This species attained a length of only 8 or 10 feet

*American Museum of Natural History*

FIG 247 Dinosaur nest with broken eggs weathering from the rock The eggs are about 4½ inches long and are believed to be those of *Protoceratops* Djadochta beds, Gobi Desert, Mongolia

greatest living rhinoceros. Pieces of dinosaurian eggshells have also been found at the top of the Cretaceous (Lance) near Red Lodge, Montana.[6] The duckbills and the horned dinosaurs outlived the others and are common fossils in parts of the Laramie group (especially the Lance beds).

Curiously, no dinosaurs were known in the far western Cretaceous until 1936, when abundant bones of a trachodont were found near Patterson, California.

FIG. 248. A mosasaur, *Clidastes*, from the Niobrara chalk in Kansas. After S. W. Williston. The animal was 12 to 15 feet long.

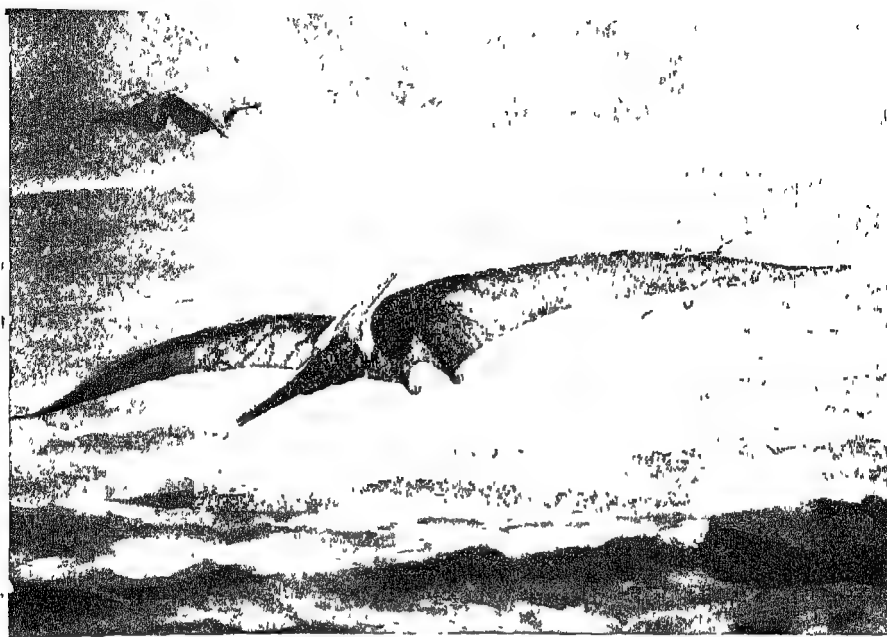
**Reptiles of the Sea.** Ichthyosaurs passed their heyday before the close of the Jurassic and were unimportant in the Cretaceous seas. On the other hand, the clumsy *plesiosaurs*, though less numerous than before, attained their greatest size. One species of these (*Elasmosaurus*), found well preserved in the Niobrara chalk of Kansas, reached a length of 40 to 50 feet, of which about half consisted of a very slender, agile neck. The dominant group of marine reptiles was a newly evolved tribe, the *mosasaurs* (Fig. 248), which made its appearance at this time. At first sight mosasaurs might be mistaken for ichthyosaurs, but there are four obvious points of difference which prove that they represent a wholly distinct order of reptiles, more closely related to the lizards and snakes than to the ichthyosaurs. First, they had scaly skins like a snake. Second, the lower jaw had extra joints, one at the chin and one near the middle of each side, which permitted the mouth to widen as it gaped (exactly as in a snake) so that very large animals could be swallowed. Third, the limbs were less specialized than those of ichthyosaurs, being simple five-fingered flippers. Finally, the tail flukes were quite differently shaped. The mosasaurs were obviously rapacious carnivores and the most ruthless pirates of the Mesozoic seas. The largest reached a length of about 35 feet. Marine *turtles* were present, and one specimen of phenomenal size (*Archelon*) has been found in the Pierre shale of Wyoming, measuring 11 feet in length

U S NATIONAL MUSEUM

*Fig 249 Pteranodon, the greatest of the pterosaurs A reconstruction made under the direction of S P Langley, pioneer in aviation studies The wing spread of this pterosaur was between 23 and 25 feet*

and 12 feet across the flippers In the rivers both broad-nosed and narrow-snouted crocodiles were common

**Last of the Winged Dragons** *Pterosaurs*, though less varied and numerous than before, were large and remarkably specialized The largest known form, *Pteranodon*, had an extraordinary wing spread of 23 to 25 feet, thus greatly exceeding any other winged creature of all time Even so, the body was not larger than that of a wild goose, and with its delicate hollow bones the creature must have been almost as light and fragile as a kite The remains of *Pteranodon* are found in the Niobrara chalk in Kansas far from the Cretaceous shoreline (Fig 249), and it was clearly adapted to soaring over the waves like the modern albatross In fact, this great reptile would have been quite helpless on the ground, for the hind limbs were so small and degenerate that they probably could not have borne even its light weight Everything had been sacrificed to the achievement of sustained flight

Unlike the Jurassic pterosaurs, the known Cretaceous species were toothless, their horny beaks displaying a remarkable parallelism with those of the post-Mesozoic birds

### *Birds with Teeth*

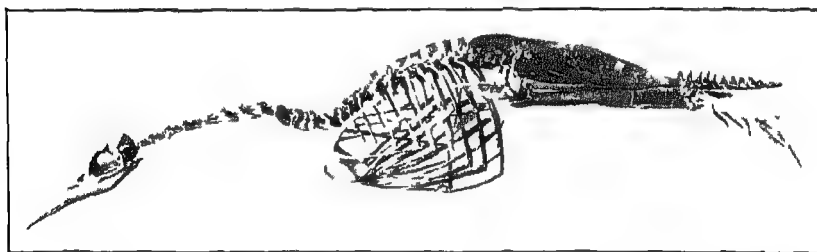
With one exception, all the birds yet discovered in Mesozoic rocks had teeth Aside from the three Jurassic specimens, these are all from the Cretaceous The greatest number of specimens have come from the Niobrara chalk of Kansas Two very distinct types of birds are known, both obviously adapted to marine life The one was a small shore bird with powerful wings (*Ichthyornis*), known only from two unique specimens at Yale, the other is the large diving bird, *Hesperornis* (Fig. 250), of which many skeletons have been found and sev-

*Yale Peabody Museum*

FIG 250 The great diving bird, *Hesperornis regalis*, from the Niobrara chalk of Kansas, mounted in diving posture Note the long tail and vestigial wings Over-all length about 4½ feet

eral have been articulated and mounted in lifelike position This remarkable bird, like the living penguin, was so perfectly adapted to life in the water that it had lost the power to fly and had only internal vestiges of wings It reached a length of nearly 6 feet, standing about 4½ feet high (if, indeed, it could stand at all) Its long slender jaws were armed with pointed, conical, but recurved teeth, well adapted to capturing and holding slippery fishes and perhaps squids The tail was several inches long but not nearly so long as that of *Archæopteryx*

It is obvious that these two highly specialized marine types do not fairly represent the bird faunas of the time Recently a well-preserved lower jaw of a toothless bird was found in nonmarine strata of Late Cretaceous age in the Red Deer Valley of Alberta Otherwise, toothless and land-dwelling birds are still unknown in the Cretaceous, but this is not surprising, since bird bones, besides being small and fragile, are hollow and air-filled, and easily destroyed Even in near-recent deposits birds are generally the rarest of fossils

### *Mammals Bide Their Time*

So long as the dinosaurs held their own, and the grasses, cereals, and fruits had not become generally distributed, the primitive mammals could only bide their time Thus far, almost all the known Cretaceous mammals come from the Laramie group and its equivalents at the top of the system Among these the *multituberculates* persist, but the other three Jurassic orders are missing and presumably were extinct However, two new orders now made their appearance, having evolved out of the Jurassic *pantotheres* before the demise of the latter These new stocks were the *marsupials* (pouch-bearers like the opossum) and the *insectivores* (Fig 251) (primitive placental mammals

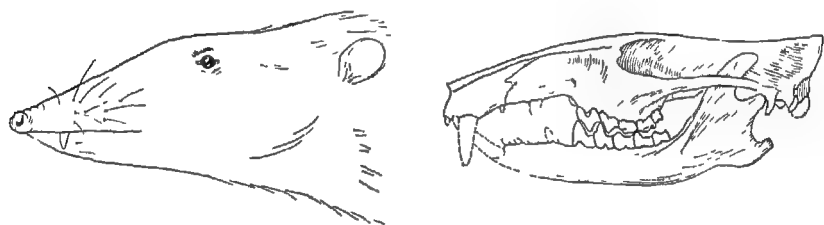



Fig 251 A Cretaceous insectivore, *Zalambdalestes lechei*, from Mongolia Flesh restoration (left) and composite reconstruction of skull (right), after G G Simpson Natural size

of the group to which modern shrews and moles belong) Some of the Cretaceous marsupials were remarkably similar to the modern opossum

### *Modernization of the Invertebrates*

By Cretaceous time the evolution of most of the invertebrate tribes had been practically accomplished, and nothing but details (genera and species) were left for the Cenozoic era Only the *ammonites* and *belemnites* gave the marine faunas a medieval aspect Both were on a decline numerically, though the ammonites still played a conspicuous role until the final ebb of the Montanan sea Many species forsook their symmetrical plan of coiling, and developed bizarre shapes, some became spiral, like a snail's shell, a few straightened, many became loosely coiled, and a few lost all semblance of regularity or symmetry (Pl 16) The significance of this extraordinary development in a decadent race is not fully understood In the figurative language of Barrell, "they seem to have been writhing in the death agony of their race" In any event, not a single species lived past the end of the Cretaceous

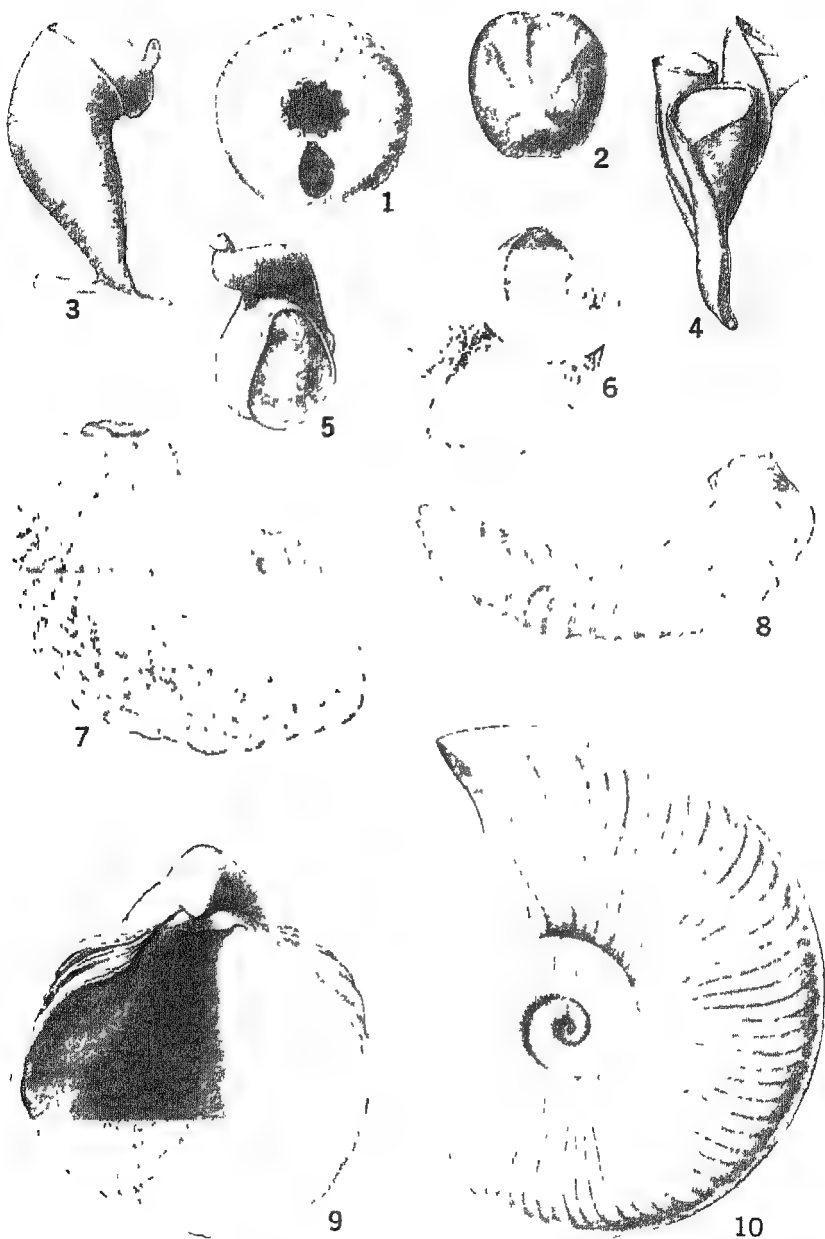



Plate 15 Lower Cretaceous Echinoids (1, 2), Clams (3–9), and Ammonite (10)

Fig. 1, *Holectypus planatus*, 2, *Enallaster texanus*, 3, *Monopleura pinguiscula*, 4, *M. marcida* (a cluster of three), 5, *Exogyra arietina*, 6, *Toucasia patagiata*, 7, *Exogyra texana*, 8, *Alectryonia* cf. *A. carinata*, 9, *Gryphæa tucumcari* (inner view of larger valve), 10, *Oxytropidoceras acutocarinatum*. All natural size. Drawn by L. S. Douglass.

Plate 16 Upper Cretaceous Cephalopods

Figs 1, 2, *Prionotropis woolgari* (young shell and ventral view of fragment of large shell), 3, 4, *Baculites compressus*, a straightened ammonite (a juvenile shell, ×3, showing initial coiled stage, and a section from an adult shell showing sutures), 5, *Mortoniceras texanum* (edge view of a shell with living chamber broken away revealing last septum), 6, *Belemnitella americana*, one of the last of the belemnites, 7, 8, *Placenticeras lenticulare*, lateral and edge views, 9, *Heteroceras* sp, an ammonite irregularly coiling at maturity, 10, *Scaphites nodosus* All natural size except Fig 3 Drawn by L S Douglass

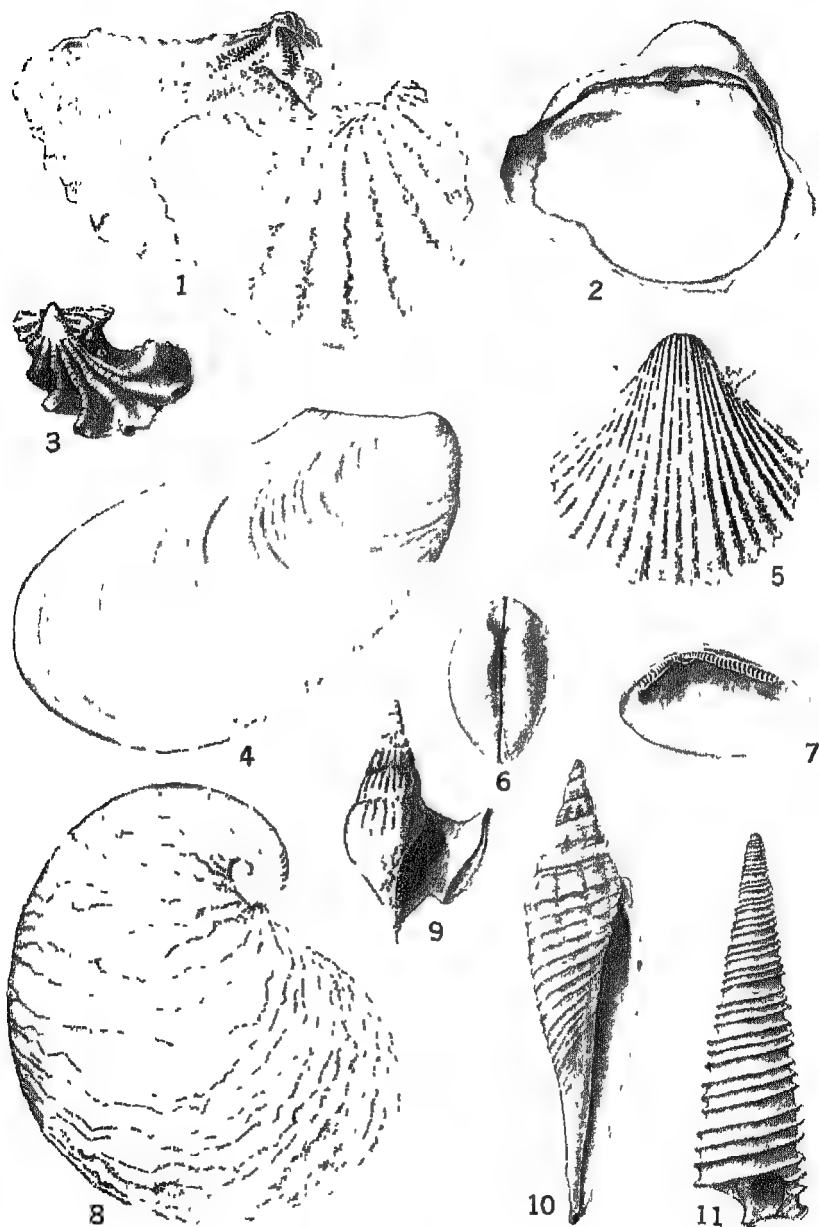



Plate 17 Upper Cretaceous Pelecypods (1–8) and Gastropods (9–11)

Fig 1, *Trigonia thoracica* (valves parted to show interior), 2, *Gryphæa convexa* (showing unequal valves), 3, *Alectryonia placenta* (a ribbed oyster), 4, *Inoceramus labiatus;* 5, *Pecten (Neithea) quinquecostata,* 6, 7, *Nucula percrassa* (dorsal view and interior of right valve), 8, *Exogyra ponderosa* (×⅓), an oyster-like clam with spirally twisted beak, 9, *Anchura lobata,* 10, *Volutoderma appressa,* 11, *Turritella trilira.* All natural size, except Fig. 8. Drawn by L. S. Douglass.

*Clams* (Pl 15, figs 3–9, Pl 17, figs 4–8) and *gastropods* (Pl 17, figs 9–11) of many kinds and of essentially modern appearance were abundant, but there was also a remarkable development of sessile, reef-making clams (*chamids*, Pl 15, figs 3, 4, 6, and *rudistids*) that gave a distinctive element to many of the Cretaceous faunas Several of these were attached by the beak of one valve This valve then grew up into a deep conical shell while the opposite valve served as an operculum Many of these shells resemble corals and, like the latter, they contributed actively to the reefs in the Cretaceous seas One form in Jamaica grew 5 feet tall *Oysters* (Pl 15, figs 8–9, Pl 17, fig 3) were very common, and two related stocks, the Exogyras and Gryphæas, are among the most distinctive invertebrates of this time

Brachiopods were no more common than they are today, and are abundant only locally in Cretaceous rocks Corals were plentiful in Europe but not in America Siliceous sponges also were important reef makers in Europe but are seldom seen here The *heart-urchins* are particularly common in the Comanche series of Texas and in the Upper Cretaceous of Europe *Crabs* were common in the sandy sublittoral zone, then as now

Insects are not common fossils simply because suitable deposits have not been found, but it is fairly certain that all the chief modern types were already represented Probably early in the Cretaceous the insects adapted themselves to feeding upon the nectar of the newly arisen flowering plants and thus gradually assumed their important role in pollenization One of the most remarkable recent discoveries is a fossil wasp nest from the Upper Cretaceous of Utah

## Close of the Period "The Time of the Great Dying"

The end of the Cretaceous, like the close of the Paleozoic, proved to be a great crisis in the history of life Several stocks of animals declined markedly *during* the period, others flourished till near its end only to become extinct For example, the dinosaurs were highly varied and apparently adaptive right up to the end of Laramie time, yet not one is known to have lived to see the dawn of the Cenozoic era The pterosaurs specialized perhaps too far, attaining their greatest size only to die out considerably before the close of the period Among the great marine reptiles, the ichthyosaurs and plesiosaurs were already on a marked decline, while the mosasaurs underwent a meteoric evolution, yet all these died out and only the marine turtles sur-

vived The decline and extinction of the ammonites and belemnites at the very close of the period, and the passing of the several stocks of reef-forming clams (rudistids) show that the marine invertebrates did not escape the crisis

It is difficult to account for the simultaneous extinction of great tribes of animals so diverse in relationships and in habits of life Perhaps no single cause was responsible The great restriction and final disappearance of the epeiric seas at the end of the era, the rise of highlands from Alaska to Patagonia, a sharp drop in the temperature accompanying the Laramide uplift, the vanishing of the swampy lowlands, and the vastly changed plant world have all been invoked to account for the extinction, and the consequent rising of the weak and lowly into new kingdoms Whatever the cause, the latest Mesozoic was a time of trial when many of the hosts were "tried in the balance and found wanting"—wanting in adaptiveness to the new environment Walther has picturesquely called it "The time of the great dying"

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## Collateral Reading

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A literary gem

*The Dinosaur Book*, by E H Colbert American Museum of Natural History New York, 1945

# V THE MODERN WORLD UNFOLDS

## CHAPTER 17

## PHYSICAL HISTORY OF THE CENOZOIC ERA

**General Features.** Every feature of the modern landscape was shaped during the last short era of geologic time The Alps and the Himalayas have come up from the sea floor, the Rocky Mountains have been worn down and then uplifted to their present height, the Appalachian ridges have been etched into relief, and all the other mountain ranges of the world have been elevated and sculptured to their present form since the beginning of the Cenozoic era The streams also have attained the courses they now follow, and climatic zones have assumed their modern character During this time also, the mammals evolved from unimpressive Mesozoic forebears to culminate in man This era saw the modern world unfold!

It was a time of crustal unrest, lying between the Laramide revolution and the Cascadian-Alpine revolution from which we are just emerging Movements still continue in many parts of the world where active volcanoes and violent earthquakes mark mobile zones still "alive" The climax of the disturbance is but recently past, if, indeed, we have seen its culmination, and the Earth is now in a rather exceptional stage of its history, the continents being abnormally large and emergent, the highlands more extensive and the mountains more lofty than normal, and the climatic zones more strongly diversified For this reason the landscape is more varied, the scenic features grander, and the Earth as a whole more interesting than it has been during much of the geologic past Since every surface detail can be traced to Cenozoic history, no other part of the geologic record has such a direct appeal

The Cenozoic was the shortest of the eras, embracing but a single period of time, probably not exceeding 70 million years The Mesozoic era was at least twice as long, and the Paleozoic five or six times as long In this striking fact there is food for thought The great

diastrophic movements during the last 500 million years, at least, have come at shorter and shorter intervals. Does this presage a time when the continents will stand still higher or be permanently emergent, and epeiric seas like those of the past will vanish for good, or will the pendulum swing back? The problem is too vast and our data are too few as yet to justify a positive belief.

**History of Subdivision.** The first attempt to subdivide the geologic record and establish a chronology goes back to the year 1759 and to Giovanni Arduino, a professor at the University of Padua. He had studied the southern Alps and the plains of Italy and recognized there four divisions of the Earth's crust formed one after another. These were: (1) the core of the mountains formed of crystalline rocks (plutonic and metamorphic), (2) the flanks of the mountains formed of limestone and marble, commonly fossiliferous and steeply dipping or strongly folded, (3) foothills composed of gravels, sands, and marls, and including the volcanics such as those about Vesuvius, and (4) alluvial material over the surface.

Arduino called the crystalline rocks *Primary,* because they were obviously the first formed of this series, the deformed and well-indurated strata of the mountain flanks he called *Secondary,* and the unconsolidated sediments of the Italian plain he named *Tertiary.* A fourth division, *Quaternary,* was added about the year 1830 to include the glacial, fluvial, and lake deposits that cover much of western Europe and that were originally thought to be the deposits left by the Biblical flood.

Arduino's scheme of subdivision, based on the degree of metamorphism, the structure, and the degree of induration of the rocks, was natural for the region he knew. Unfortunately, it was soon applied to other parts of Europe and was used as a general scheme of classification both there and in America until after 1800. Yet obviously it could not serve as a universal scheme unless all mountain ranges were of the same date and had a similar history. We now know, as Arduino did not guess, that some mountain ranges are ancient and others relatively young, and that the granite or metamorphic core of one range can not be assumed to be of the same date as that of another remote mountain system. As this fact was realized, about 100 years ago, Arduino's scheme of classification was abandoned and the terms Primary and Secondary were dropped, but, curiously, the term Tertiary was perpetuated and used for the pre-Glacial formations that we now call Cenozoic, while the term Quaternary persisted

for the deposits of the Pleistocene ice age It is still common practice to subdivide the Cenozoic rocks into Tertiary and Quaternary systems, but this is certainly no longer justifiable, the Quaternary (= Pleistocene) is merely a short epoch of the Cenozoic era of which there is yet but a single period The words Tertiary and Quaternary are vestiges of a misconception long since outgrown, and they should be abandoned

Fig 252 Sir Charles Lyell (1797–1875)

The Cenozoic rocks were first critically studied in the Paris basin, where richly fossiliferous marine strata alternate with nonmarine formations As the beautifully preserved faunas of these rocks were described and analyzed by the French paleontologists, notably by Deshayes, it became evident that the uppermost marine beds contained many species of shell-bearing molluscs that still live in modern seas, and that fewer and fewer of these living forms were present in successively older horizons Grasping this idea, the great English geologist, Lyell, proposed a classification based on the percentage of still-living shelled invertebrates, and coined names for several *series* of the Cenozoic rocks accordingly This scheme as eventually perfected is still in use, and may be expressed in tabular form as follows

| | | | |
|---|---|---|---|
| Pleistocene series (Gr *pleistos*, most, + *kainos*, recent) | 90–100% | modern | species |
| Pliocene series (Gr *pleion*, more, + *kainos*) | 50– 90% | " | " |
| Miocene series (Gr *meion*, less, + *kainos*) | 20– 40% | " | " |
| Oligocene series (Gr *oligos*, little, + *kainos*) | 10– 15% | " | " |
| Eocene series (Gr *eos*, dawn, + *kainos*) | 1– 5% | " | " |
| Paleocene series (Gr *palaios*, ancient, + *kainos*) | 0 | " | " |

Lyell originally proposed only the three terms, Eocene, Miocene, and Pliocene, the others have been added later It is now known that the exact percentage of living species in rocks of a given date varies from region to region and is not a satisfactory basis of correlation,
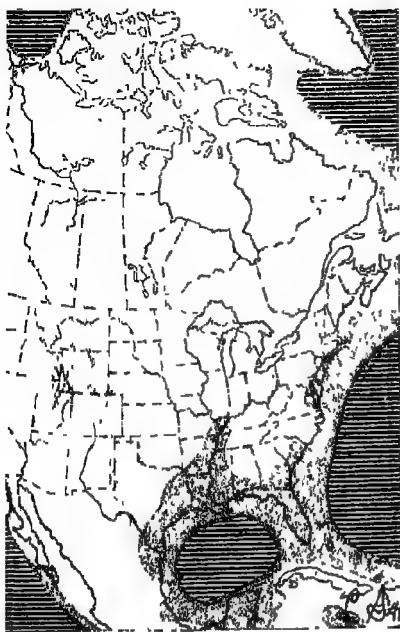
*Fig 253A (left) Eocene paleogeography Note that shallow sea overlapped most of the present Atlantic and Gulf Coastal Plain and reached northward to Cairo, Illinois*

*Fig 253B (right) Oligocene paleogeography Note that the Cordilleran region is now nearly peneplaned*

*Fig 253C (left) Pliocene paleogeography Renewed uplift and deep erosion have now restored strong relief in the Rocky Mountain region, and the Basin and Range Province has developed its modern aspect*

but the six series of strata (and six epochs of Cenozoic time) are nevertheless recognized throughout the world

The Cenozoic history will be treated at greater length than that of previous periods because we can read more detail from the rocks and because they help to explain the features of our modern world

## Cenozoic History of North America

At the close of Cretaceous time North America assumed approximately its present size and configuration The Atlantic and Gulf coastal plains were partly submerged from Paleocene to Oligocene epochs but emerged more and more completely thereafter (Fig 253) Small embayments covered parts of California, Oregon, and Washington, and, for a very brief time at the beginning of the era, a seaway covered a small part of the northern Great Plains The maximum submergence, however, scarcely flooded 10 per cent of the present lands, and the average for the era was only about 3 per cent

The stratigraphic record therefore lies chiefly in nonmarine formations which, fortunately, are both widespread and richly fossiliferous A study of land forms also adds much to our knowledge of Cenozoic history Remnants of uplifted peneplanes, for example, tell of erosion cycles and give a measure of uplifts in both the Appalachian and Rocky Mountain regions

The history can best be told by natural regions, taking each in its turn

### *Eastern North America*

**Coastal Plain Overlap.** From New Jersey to Mexico the outer part of the coastal plain is formed of Cenozoic formations Like the Cretaceous beds, they are but slightly consolidated sands, clays, and marls, dipping gently seaward Eocene and Miocene beds are most widespread along the Atlantic coast, especially in the Chesapeake Bay region, where both are marine and richly fossiliferous Paleocene and Eocene clays and sands are most widespread along the Gulf border, commonly reaching 100 to 200 miles inland, and in the Mississippi Valley extending up to Cairo, a distance of 600 miles from the coast In the central and western Gulf Coastal Plain the Paleocene (Midway) and early Eocene (Wilcox) formations are largely nonmarine and contain much lignite, showing the influence of the Mississippi River and its tributaries, which maintained a broad swampy coastal lowland here during early Cenozoic time.

Oligocene formations are in general less extensive, but in Florida and Central America they are widespread. In both these regions they are largely calcareous, but in the central and western Gulf area, where the influence of the Mississippi River was strong, the Oligocene is represented by thick clays and sands. Miocene and Pliocene formations are generally still more restricted, showing that the eastern and southern margins of the continent were progressively emerging.

Along the Atlantic border the Cenozoic formations form a great wedge, thickening seaward to beyond the present coast. From a feathered edge at their landward margin, they thicken to 700 to 1000 feet at the coast. A deep well on the barrier beach at Cape Hatteras, however, has revealed a thickness of 3034 feet of Cenozoic strata.[1] Not only do these formations dip seaward, but the older ones dip more steeply than the younger, proving that the continental shelf has been tilted somewhat during deposition.

Along the central Gulf border rapid subsidence has been counterbalanced by the growth of the Mississippi delta, and there Cenozoic formations reach an impressive thickness. Oil wells along the Louisiana coast are still in Miocene beds at a depth of 12,000 feet, and a study of regional dips and data from deep wells indicates a thickness of probably 30,000 feet of Cenozoic deposits under the coastal margin of Louisiana.[2] This is more than twice the maximum depth of the Gulf of Mexico and indicates excessive downwarping and suggests a geosyncline in the making (Fig. 254). The axis of this trough approximately parallels the present coast line of Louisiana and Mississippi.

Florida is made largely of Cenozoic limestones resting on a Cretaceous floor. These reach a maximum thickness of more than 5000 feet and represent all the epochs of the Cenozoic. For the most part they are clearly the deposits of a shallow sea and indicate that Florida was not a peninsula but a shallow submarine bank during most of the era. The finding of vertebrate fossils near Gainesville, however, has led to the discovery that during a part of the Miocene epoch a large low island existed over the central part of the state.[3] A fauna of 22 species, including three-toed horses, deer, rhinoceroses, and carnivores, was found in the fill of a stream channel that was cut during the period of emergence. There is also reason to believe that central Florida was emergent at the close of the Eocene epoch, and perhaps for short periods at other times in the era. Until the Miocene, Florida was too far from shore to be reached by detrital sediment, but since that epoch its eastern border has received considerable fine sand, car-

ried southward by shore currents from the streams that reach the Carolina coast. This, for example, is the source of the sand at Daytona Beach.

**Origin of the Gulf of Mexico.** A belt of Cretaceous and Cenozoic formations encircles the Gulf of Mexico, forming a low coastal plain from Florida to Yucatan. These formations obviously accumulated under conditions approximating those of the present, and make it certain that the Gulf of Mexico was then in existence. Deep wells
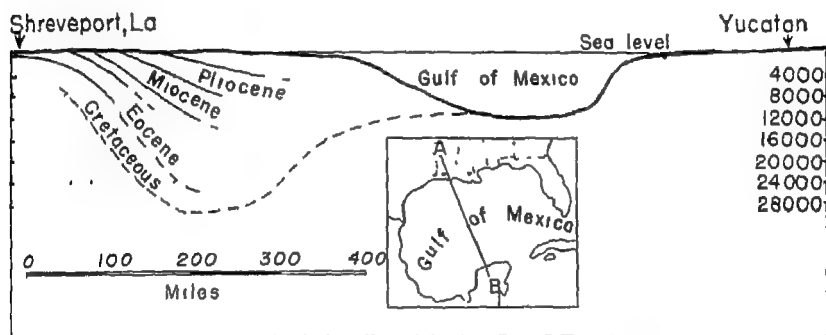
Fig. 254. Section across the Barton geosyncline and the Gulf of Mexico. The inset shows the position of the section, which runs from Shreveport, Louisiana, to Yucatan. The axis of the geosyncline follows the broken line in the inset map. Depths below sea-level indicated in feet. Modified from Barton, Ritz, and Hickey.

have revealed that Jurassic formations also underlie the western Gulf coastal plain, dipping seaward with the Cretaceous beds.

On the contrary, the pre-Jurassic rocks of the Gulf region have a very different arrangement. In the Antillean Islands they are metamorphic and volcanic and appear to be remnants of a deformed land mass. In Florida a deep well has revealed Cretaceous beds resting on deformed Cambrian or early Ordovician strata.[1] Furthermore, the late Paleozoic formations of the Ouachita trough indicate that Llanoria was a rugged upland in the western Gulf region as late as Permian time. It may be inferred, therefore, that this great depression began to form in Jurassic time and that it was well outlined in the Cretaceous period, but its present depth may be the result of Cenozoic movements.

**Sculpturing of the Appalachians.** At the beginning of the Cenozoic era nearly all the Appalachian region was peneplaned, the exceptions being a chain of monadnocks rising to 2000 or 3000 feet along the border between eastern Tennessee and North Carolina, and scat-

tered hills in northern New England These unreduced areas form the crest of the modern Great Smokies, the summit of the White Mountains, and such scattered peaks as Mount Katahdin and Cadillac Mountain in Maine, they show no evidence of ever having been reduced to a level summit Elsewhere in the Appalachian region, however, remnants of a widespread and remarkably flat erosion surface may be seen in the even crests of the highest ridges (Fig 255) and in the summits of the Allegheny Plateau. This old surface has been
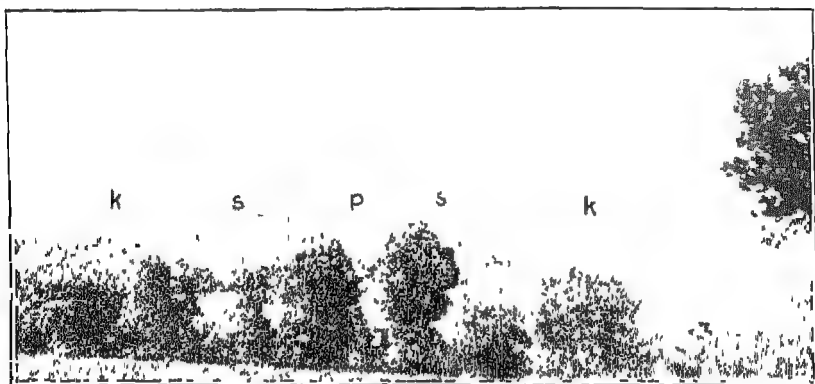
Fig 255 Remnants of the Schooley peneplane are seen in the accordant crests of these Appalachian folds The view is westward into the Susquehanna Gap at Harrisburg, Pennsylvania, showing Kittatinny Mountain (*k*) with Second Mountain (*s*) and Peters Mountain (*p*) beyond it

named the *Schooley peneplane* When it was formed, the surface must have been near sealevel, and the region was obviously a low plain

The present mountains are therefore due almost wholly to Cenozoic changes However, they are not the result of either folding or faulting but of (1) *gentle regional upwarp,* which produced the present elevation, and (2) *sculpturing by erosive agents* that have carved out the weaker rocks and created the local *relief* The mountain *structures* were already present, inherited from the Appalachian revolution and the Palisade disturbance

The erosional history of the region is suggested in Fig 256 After the completion of the Schooley peneplane (block 2), at a time not yet accurately dated, the region was gently arched and uplifted a few hundred feet (block 3) The streams then incised themselves to the new baselevel and opened out extensive lowlands on the weak formations, while the resistant rocks stood up as ridges (block 4) Rem-

nants of these flat lowlands are still conspicuous about Harrisburg, and this flat erosion surface, present on the weak formations only, has been named the *Harrisburg surface*

A second gentle upwarp along the axis of the Appalachians caused the streams to incise their valleys into the Harrisburg surface and to
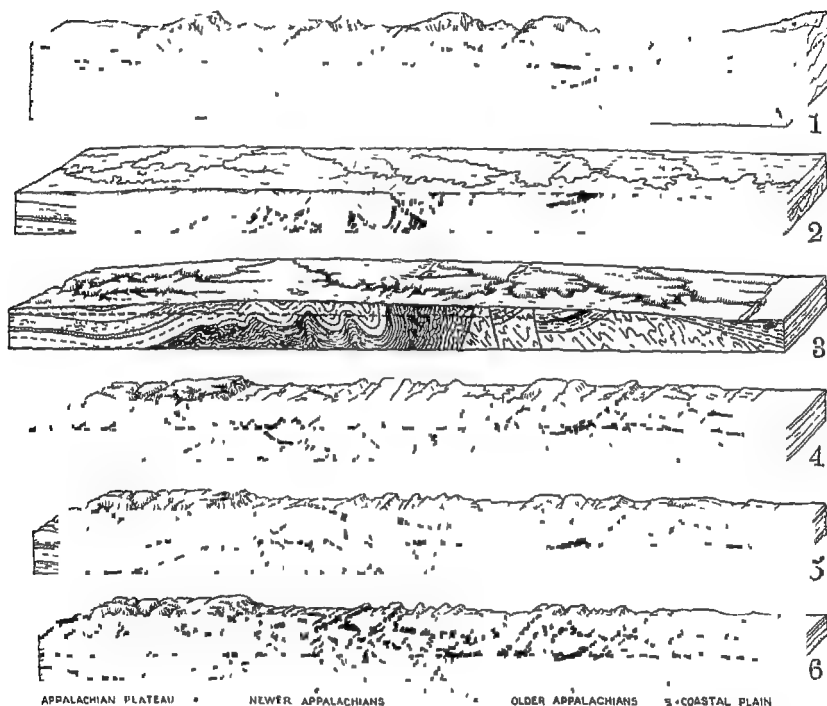
Fig 256 Evolution of the modern topography of the Middle Appalachian region

1 Rough topography of early Jurassic time, resulting from dissection of the structure produced by the Appalachian revolution and the Palisade disturbance
2 Development of Schooley peneplane
3 Arching of Schooley peneplane and incision of drainage
4 Dissection of Schooley peneplane and local development of Harrisburg erosion surface beveling belts of weak rock
5 Further uplift and dissection, with development of a lower erosion surface (Somerville) beveling only the weakest rocks
6 Latest uplift and dissection Modified slightly from D Johnson

excavate new lowlands of more local extent at a lower elevation (block 5) Still younger and more frequent uplifts of this sort have given rise to strath terraces along the major streams as they carved their present deep valleys Thus by a series of gentle uplifts the Schooley peneplane has been warped up to its present maximum height of about

4000 feet along the crest of a broad simple arch, and the ridges and valleys have been etched into relief From an axis running near the eastern edge of the Allegheny Plateau, the surface of the old Schooley peneplane slopes gently away to the east, and possibly to the west, declining but a few feet to the mile It is preserved only on the most resistant rocks and has been completely destroyed throughout most of the piedmont belt. If it could be restored, it would have the form of a vast low arch several hundred miles wide and less than one mile high along the crest of the Appalachians Near the present coast it would descend to sealevel and pass under one of the coastal-plain formations, for it is clear that, as the Appalachian arch came up, the continental shelf was depressed and tilted eastward If stages of uplift in the mountains could be correlated with deposits in the coastal-plain region, the erosional history could be dated in detail, but unfortunately such correlations are not yet secure

### *The Central Interior*

Throughout Cenozoic time the great interior of the continent stretching westward from the Appalachian Plateau to the Great Plains was a lowland undergoing but slight degradation The stages in its development are far more obscure than are those of the Appalachian region River gravels widely distributed over the interstream areas bear evidence that the surface has been reduced to its present form by long-continued stream erosion and mass wasting

In the Great Lakes region, where the Paleozoic formations overlap upon the Canadian Shield, the beveled edges of the more resistant limestones were brought into relief as cuestas, while the weaker formations were reduced to broad lowlands which, in the Pleistocene epoch, were modified by glaciers to form the basins of the Great Lakes

### *Decay and Rebirth of the Rockies*

**Basin Filling and Peneplanation.** Nearly all the major *structures* of the Rocky Mountains date from the Laramide revolution at the end of the Cretaceous As noted before, the folding and faulting continued locally into the Eocene, and died out gradually This left the region bold and mountainous in early Cenozoic time

Among the ranges there were several great structural basins which have persisted, with little deformation, up to the present (Fig 257) Such are Powder River, the Big Horn, and Green River basins of Wyoming, and the Uinta basin and North and South parks in Col-
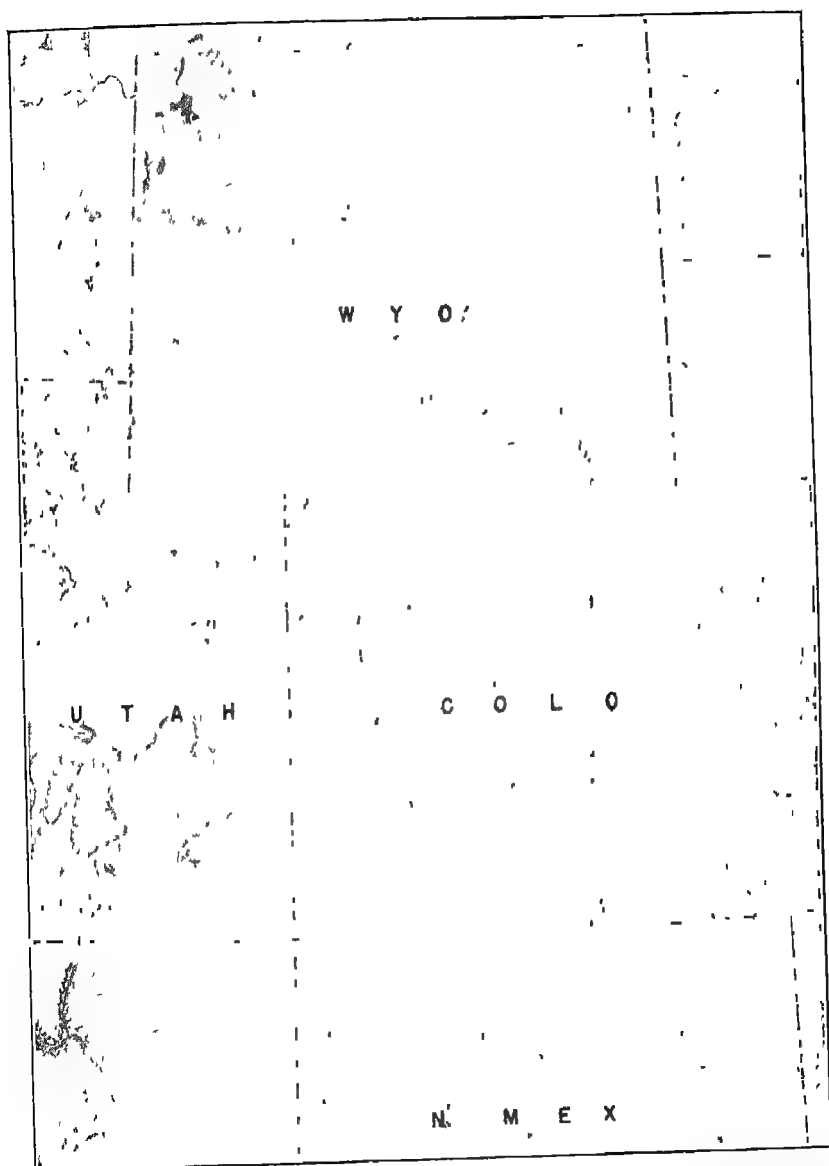
Fig 257 Structural basins within the middle and southern Rocky Mountains The topography is that of the present, but the structure dates from the Laramide revolution Drawn by Milton Wallman

orado As the mountains were eroded, the sediment converged into these basins, where much of it was trapped Fans formed about the margins, but most of the debris was spread as broad alluvial deposits across the basin floors Thus they were gradually filled as the mountains were worn down Meanwhile, through-flowing streams were aggrading the plains region east of the Rockies By the middle of the era the intermont basins were full and the mountains were largely peneplaned to the level of this surface of aggradation, as represented
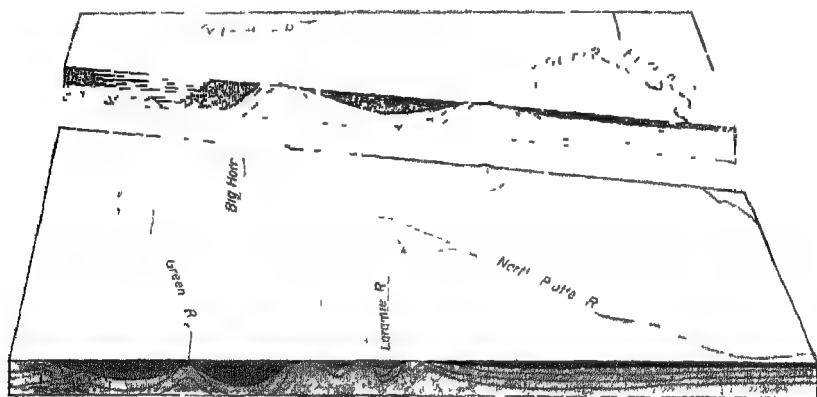
Fig 258 Block diagram of the middle Rocky Mountains and part of the Great Plains as they were in Miocene time, when the basins were filled with Cenozoic deposits (*black*) and the ranges were peneplaned to the level of this aggraded plane Monadnocks mark the sites of the chief ranges The block has been cut in two, and the pieces have been parted to show the structure along a line passing through Yellowstone Park and the Black Hills In the area of Yellowstone Park and the Absaroka Plateau, volcanics (*white*) largely replace the sedimentary deposits The streams flow for the most part upon alluvial deposits which hide the buried ranges Suggested by a figure by Atwood and Atwood

in Fig 258 Along the axes of some of the ranges, rounded monadnocks stood a few hundred or even 2000 to 3000 feet above the peneplane, but for the most part the mountains were then buried in their own debris, and the streams wandered widely over this thick alluvial cover

This flat surface of combined erosion and deposition was probably 2000 or 3000 feet above sealevel, because the streams had hundreds of miles to flow before reaching the sea and even a very low gradient would leave considerable altitude at their source Peneplanation had been accomplished by late Oligocene time

**Cascadian Uplift and Erosional Sculpturing.** In Miocene and Pliocene time uplift was resumed, not in the form of local deformation but rather as a broad upwarp of the whole region into a low arch

hundreds of miles across It correlates in time with the Cascadian deformation farther west, and may therefore be spoken of as a Cascadian uplift This movement continued intermittently, but with acceleration, to a culmination in the late Pleistocene, and brought the peneplaned surface to a maximum elevation of 10,000 to 11,000 feet along the continental divide With this uplift the streams were rejuvenated and began to deepen their valleys, to re-excavate the basins, and to sculpture the exhumed mountain masses Thus the *height* of
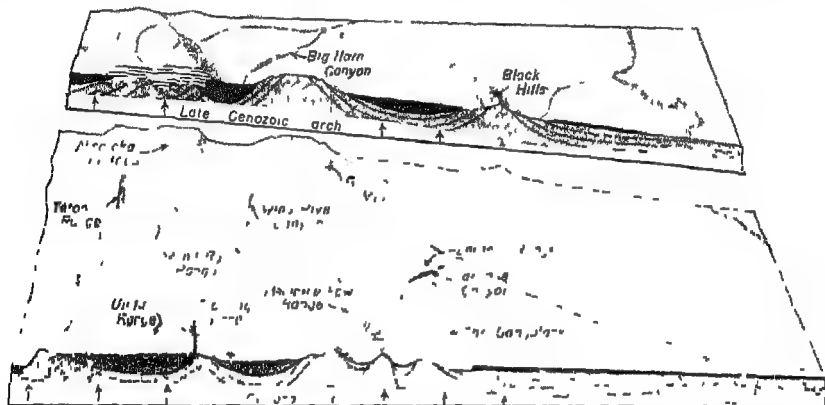
FIG 259 Block diagram of the same region as Fig 258, showing the present relief which is due to (1) broad regional arching during post-Miocene time, and (2) excavation of much of the weak fill from the basins In the removal of the Cenozoic fill the streams were in many places superposed on the ranges, which they now cross in imposing canyons

the Rockies is due to broad regional upwarp, but their present *form* and *relief* were determined by late Cenozoic erosion (Fig 259)

Thus far it has been assumed that all parts of the Rocky Mountain region were peneplaned at the same time, and only once This picture is undoubtedly too simple Within a region so vast, the ranges possess individuality in structure and in lithology, and probably moved with some independence The final uplift was long and intermittent, and a series of partial peneplanes were probably formed locally as the baselevel changed—indeed, there is clear evidence of more than one in many of the ranges Nevertheless, in most parts of the region, remnants of one peneplane are so much more striking than any others that they appear to belong to one general *Rocky Mountain peneplane* If, instead of one, there are several peneplanes in the Rocky Mountains, then the history is more complicated in its detail, but in fundamentals it is essentially as outlined above
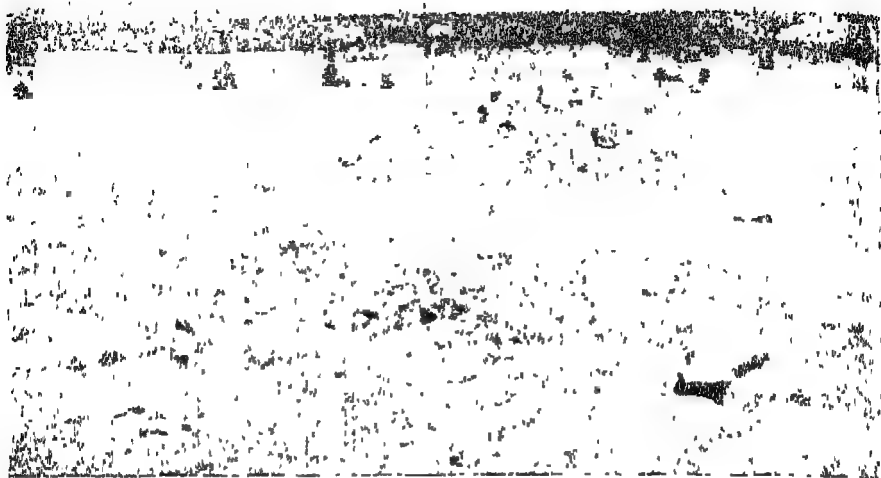
*Fig 260 Peneplane on the granite summit of the Laramie Range The view is north from a point near Buford, Wyoming Monadnocks rise above the peneplane in the distance at the left*

Evidence of the history just sketched may be seen in (1) peneplane remnants still preserved along the summits of most of the ranges, (2) remnants of the Cenozoic formations around the margins of the basins, (3) superposition of many of the streams across the present ranges, and (4) the stratigraphy of the Cenozoic formations in the High Plains east of the Rockies

These features are illustrated in Figs 259 and 261 A particularly fine peneplane remnant may be seen along the summit of the Laramie Range in southeastern Wyoming Here, at an elevation of 8000 feet, is a nearly flat surface 10 or 12 miles wide, cutting across granite and other types of igneous rock of the mountain core (Fig 260) "Roads run in almost every direction, and the Union Pacific Railroad crosses the divide, not through a deep pass but across an open plateau At the station of Sherman one may look for miles in almost any direction, and it is with difficulty that he realizes that his viewpoint is 8000 feet above sealevel, or as high as the summit of many of the rugged mountains of the Northwest" (Blackwelder)

East of the Laramie Range lie the High Plains, capped by Miocene (and locally Pliocene) beds Their surface is extraordinarily flat and slopes gently eastward to an elevation of not over 2000 feet in central

Nebraska and Kansas This great flat area is a remnant of the aggraded plain that existed when the mountains were peneplaned Generally its most elevated western margin has been dissected and eroded back several miles from the mountain front, especially where large streams cross it, but locally in southeastern Wyoming it extends up to the mountains, rising to the level of the summit peneplane Here it forms the "Gangplank" (Fig 259) by which the Union Pacific Railroad crosses the mountains from the plains Even where the High Plains beds have been eroded back several miles it can be seen that, if they were projected toward the mountains, their surface would meet the peneplaned summit

Several miles north of the "Gangplank," the Laramie River crosses the range in a granite gorge more than 1000 feet deep It rises west of the range and flows northward for some 50 miles along the floor of Laramie basin at an elevation of less than 7000 feet, and then turns east and cuts through the range instead of following the lowland northward to the Platte Such an anomalous course is easily understood if the Laramie basin was once filled with sediment that slightly covered the range as represented in Fig 258, for then the stream flowed on a graded plain from which it was superposed on the range after uplift The Cenozoic fill has been almost completely removed from Laramie basin, but a telltale remnant still exists along its western margin, flat-lying along the front of the Medicine Bow Range at an elevation of 8500 feet The greatest remnants of Cenozoic deposits at high altitudes, however, are along the southern end of the Absaroka Range, where Eocene and Oligocene strata are interbedded with, and protected by, volcanics Here flat-lying Oligocene strata at an elevation exceeding 10,500 feet rim the northern side of the Wind River basin

The course of Laramie River in crossing the range is not exceptional, the major streams flow radially out of the Rocky Mountains, crossing basins and ranges alike (Fig 261) As shown in Fig 259, Big Horn River, originating in the Wind River basin, cuts through the Owl Creek Mountains and flows for 100 miles across Big Horn basin, only to turn east and cut through the north end of the Big Horn Range in an imposing chasm Likewise, Green River flows south across Green River basin, swings east along the north side of the Uinta Mountains, and then cuts through them in the magnificent Flaming Gorge Farther south, South Platte River, heading in South Park at an elevation of about 9000 feet, flows northeast through the

Front Range in another great gorge, and the Arkansas, after flowing across South Park basin, cuts through the Front Range in picturesque Royal Gorge, whose sheer walls tower 1400 feet above the stream

All these and other anomalous features of the drainage find a simple explanation in the fact that the basins were formerly filled completely with Cenozoic sediments until the ranges were covered where the streams now cross them

*U G Cornell*

Fig 261 Canyon of North Platte River near the mouth of the Sweetwater, southwest of Alcova, Wyoming, cut to a depth of 450 feet in granite

**Stratigraphy of the Cenozoic Deposits** The fluvial deposits that were spread as an immense debris apron east of the Rockies during Cenozoic time have been partly destroyed by later erosion along both their eastern and western margins, but the great central portion is still intact in the High Plains Here they include clay, silt, and sand, with linear bodies of coarse sand and gravel marking old stream channels In general the beds are weak, and in areas of rapid erosion appear as "badlands" (Figs 263, 264) Much volcanic ash, derived from sources farther west, is included in the stream-laid deposits

The thickness of the entire deposit ranges up to 2000 feet over extensive areas but is nowhere much greater It includes formations of Paleocene, Oligocene, Miocene, and Pliocene dates, but none of these was continuous over the whole region They were deposited by streams flowing nearly at grade and ever seeking the lowest places to drop their loads The result is an intricate patchwork of formations, mostly local in character A few are more widespread and represent times of more general deposition

The oldest beds here present constitute the *Fort Union formation* of Paleocene date, which occupies a vast area in the northern Great Plains, chiefly in the Dakotas, Wyoming, Montana, and Alberta It includes friable yellow sandstones, somber gray shales, and many

zones of coal Over a considerable area in the center of the Dakotas there is present at its base the *Cannonball marine member*, with oyster banks and other evidence of shallow brackish and marine water (Fig 262) A fauna of about 150 species of marine animals has been identified from these beds (about 80 molluscs and 64 foraminifers) Until recently this marine zone was referred to the underlying Lance (= Laramie) formation of latest Cretaceous date, but study of the associated land plants and of the Foraminifera indicates that the Can-
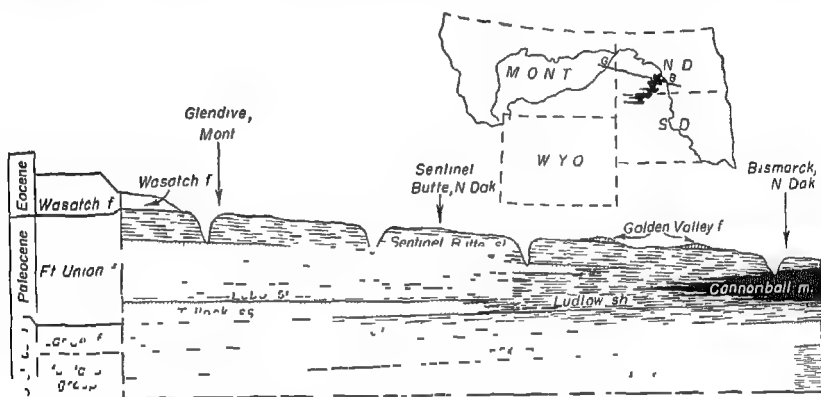
FIG 262 Stratigraphic section showing the relations of the Cannonball marine member of the Fort Union formation The inset map shows the outcrop of the Cannonball member (*black*) and the line of the section, *G–B* The Golden Valley formation of Eocene age appears as outliers near Bismarck, North Dakota Length of section, about 200 miles, vertical scale greatly exaggerated

nonball horizon is Paleocene,[5] and if so, it must be transferred from the Lance to the Fort Union formation Thirty-eight species of the Foraminifera occur also in the Paleocene (Midway group) of the Gulf coast, and of these 13 are limited elsewhere to that group

In the plains, the Fort Union formation is the chief coal-bearing horizon Here it has yielded abundant plants, but almost no vertebrate remains Farther west, however, it holds an amazing array of strange, small, primitive mammals

With the exception of small areas of Early Eocene (Wasatch) beds in eastern Montana and the Dakotas,[6] no true Eocene formations occur east of the Rockies, although they are thick and widespread in the intermont basins (Fig 266) Evidently by this time relief in the mountains was reduced somewhat, and the streams were at grade In the plains the Paleocene beds are succeeded by the Oligocene *White River group* which is widespread in Montana and Wyoming, reaching

eastward into the Dakotas and southward into Nebraska It forms the Big Badlands southeast of the Black Hills (Figs 263, 264) and is one of the most prolific sources of fossil vertebrates in the whole Rocky Mountain region It ranges from 200 to 500 feet in thickness and consists generally of clay and fine silt along with much volcanic ash The general lack of sands and gravel indicates that the region farther west had but slight relief at this time

Fig 263 Idealized panoramic section of the Big Badlands of South Dakota After H F Osborn, U S Geological Survey

The overlying *Arikaree group*, of Miocene date, is relatively coarser, including great quantities of sand It extends farther than the Oligocene beds and locally reaches a thickness of about 2500 feet, though in most places it is far thinner Recently the *Hemingford group* was defined to include Upper Miocene formations, which in the past have been included in part in the Arikaree Evidently uplift was under way in the mountain region, and the streams emerging onto the plains were once again heavily laden with sand as well as mud

The Pliocene is represented by the *Ogallala group,* which ranges from 300 to 500 feet in thickness and, like the Miocene beds, consists of clay, fine silt, sand, and gravel, mostly unconsolidated

Pleistocene deposits include glacial drift and loess north and east of the Missouri River, and very limited and patchy areas of bedded sand and gravel farther south

The character of these formations in the High Plains obviously reflects the erosional history of the mountains (Fig 265) The coarse, sandy Paleocene deposits indicate high relief in the mountain area as the streams emerged heavily loaded with sand and gravel as well as mud The lack of Eocene deposits shows that the streams then flowed at grade; evidently the relief in the mountains was con-

siderably reduced by this time The very fine grain of the widespread Oligocene deposits, both here and in the intermont basins, indicates very low relief, and the upper surface of these beds is to be correlated with peneplane remnants on the summits of the Front Range The coarser nature and the considerable thickness of the Miocene beds show that uplift in the mountain region had been resumed and the streams were once again emerging heavily laden with sand By Pliocene time arching along the axis of the Rockies had tilted the surface of the High Plains eastward so that the streams were again at grade, in most places carrying their load of debris through to the Mississippi River

The intermont basins are occupied chiefly by Paleocene and Eocene deposits which reach an aggregate thickness of several thousand feet Like the Cenozoic formations of the plains, they are mostly fluvial deposits of clay, silt, and sand Thick basal and marginal conglomerates occur in places where alluvial fans were built at the mouths of torrential streams Deposition was independent in the several basins,

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*Fig 264 The Big Badlands of South Dakota Oligocene (Brule clay) in the foreground*

the accumulation depending on the amount of subsidence, and, since the warping was irregular and intermittent, there is no complete record in any single basin Nevertheless, the abundant fossil mammals permit a correlation of zones from basin to basin and the building up of a composite sedimentary section of these oldest Cenozoic formations amounting to between 10,000 and 20,000 feet (For basins, see Fig 257 )
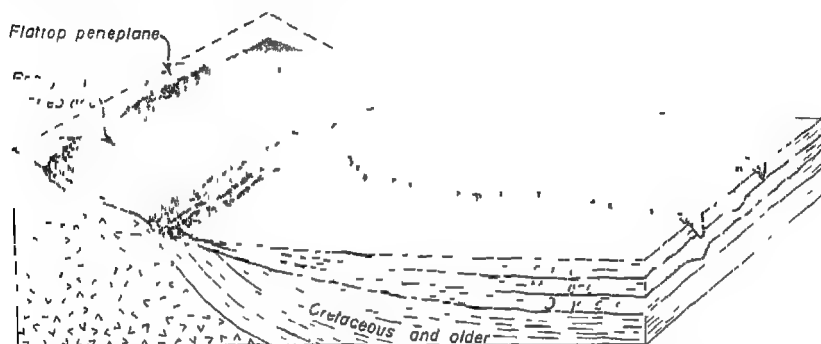
FIG 265 Idealized diagram to show the relation of sedimentary deposits in the High Plains to erosion surfaces in the Rocky Mountains It is drawn on the assumption that the Flattop peneplane was completed during late Oligocene time and the Rocky Mountain peneplane late in the Miocene epoch before renewed uplift started canyon-cutting in the mountains If this be true, the upwarped Flattop surface was once continuous with the upper surface of the Oligocene beds, and the Rocky Mountain erosion surface originally joined the erosion surface separating the Miocene from the Pliocene formations Although these correlations appear probable, they are not certainly proved because after the latest upwarp the streams have not only cut valleys in the deposits of the High Plains but also have stripped back their western margins most of the way along the front of the mountains, leaving a gap several miles wide between the remnants of the erosion surfaces in the mountains and their counterparts in the High Plains Adapted from an unpublished figure by R F Flint

These deposits, like those of the plains, commonly form badlands, a typical view of which is shown in Fig 264 Four major groups are widely recognized, three of them named from the basin where best exposed The oldest of these is the *Paleocene horizon,* which embraces the *Fort Union* and equivalent beds Next comes the *Wasatch formation* (Fig 266), marked by the first great invasion of modernized mammals, including the "dawn horse," *Eohippus* Above this comes the *Bridger formation,* with younger mammalian faunas, and finally the *Uinta formation,* with the last and largest of the archaic mammals represented by the grotesque uintatheres

The *Green River basin* of Colorado and Wyoming was occupied by a vast shallow lake during much of middle Eocene time, and here accumulated the fine, evenly bedded oil shales (so called because they

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*Fig 266 Lower Eocene (upper Wasatch) exposures along Cottonwood Draw near Lost Cabin, Wyoming*

yield oil by destructive distillation), of an average thickness of 2000 feet Around the margins of the basin, however, the lake beds grade laterally into fluvial sediments of the Wasatch and Bridger formations Most of the Green River strata are laminated, and, on the assumption that the layers are seasonal, it has been estimated that their deposition required 6,500,000 years On this basis the Wasatch required 11,000,000 years, the Bridger 4,000,000, and the Uinta nearly 2,000,000

In Montana, there are rather extensive lake deposits of Oligocene date formed in broad valleys that were obstructed by warping and local faulting These are the Bozeman Lake beds Near Florissant, Colorado, there was a similar but smaller intermont lake in early Miocene time, and its deposits form one of the richest of all localities for fossil insects and plants The sediments are largely of volcanic ash, which appears to have overwhelmed and buried the life in its fall The John Day basin of central Oregon was another intermont basin encircled by active volcanoes during late Oligocene time, and here was formed one of the richest known deposits of Cenozoic fossil mammals

*Central Cordilleran Region*

Figure 267 displays the relations of the major structural units of the Cordilleran region. On the east lie the Rockies and on the west

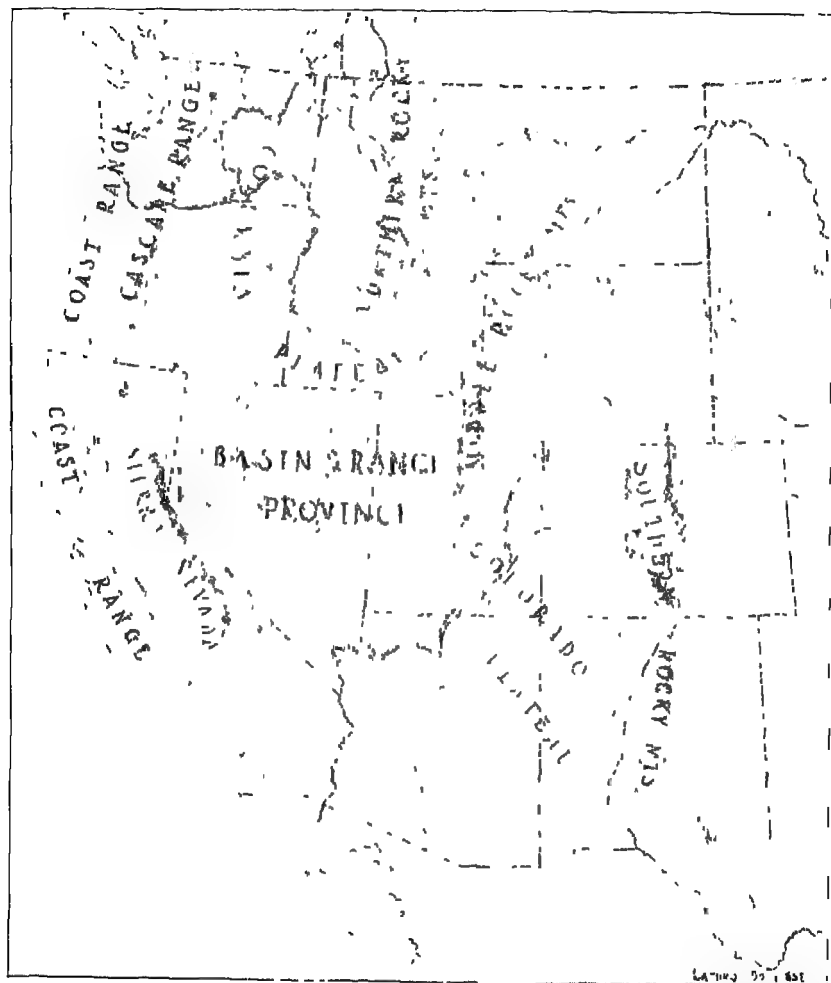



FIG. 267. Relief model of the Cordilleran region, showing the relations of its major structural elements

the Sierra Nevada and the Coast Ranges, while the central Cordilleran region is formed by the Colorado Plateau and the Basin and Range Province (which farther north gives way to the Columbia Plateau) The Basin and Range Province, with an average height of 6000

feet, lies more than a mile below the crest of the Sierra Nevada, and a few thousands of feet below the Colorado Plateau. Its ranges are tilted fault blocks of Mesozoic and Paleozoic rocks flanked round and partly buried by the Late Cenozoic sediments. The Colorado Plateau, on the contrary, consists of relatively flat-lying Mesozoic and Paleozoic formations at an elevation ranging from 7000 to 11,000 feet. The rocks of the plateau were thrown into broad swells, with local monoclinal flexures, during the Laramide disturbance, and have been broken by a number of normal faults during Cenozoic time; yet, by and large, it is a unit contrasting in simple structure with the Basin and Range Province on the one side and the Rockies on the other.

**Origin of the Basin and Range Province.** The Basin and Range Province (Fig. 267) lies in the zone of the enormous Laramide thrusts. It is probable that those movements continued into the Eocene, and that during Early Cenozoic time the region had a high mountainous surface and exterior drainage. For this reason Eocene and Oligocene strata are practically absent.

Miocene formations are present, however, and are locally of great thickness. Their character speaks eloquently of the events that were occurring. For example, in southern Nevada the Miocene deposits begin with coarse conglomerate that ranges up to 3000 feet in thickness and lies across the beveled edges of Early Mesozoic and Paleozoic strata. The conglomerate varies greatly in thickness within short distances and includes angular and subangular fragments of all the older rocks. Overlying the conglomerate are clays and silts, including thick beds of gypsum, magnesite, and borax. The conglomerate is clearly the coarse debris of fans formed in a region of bold relief, and the clays and silts, with their saline deposits, could have formed only in arid basins of interior drainage much like the present basins. In short, normal faulting had begun on a grand scale, and the Basin and Range Province had its inception in the Miocene. As the new ranges were greatly elevated during the Pliocene epoch, the intervening basins, all in the rain shadow of the Sierra Nevada, assumed a desert character like that of today. The faulting was only begun in late Miocene time, for the deposits of that age were themselves later steeply tilted and truncated so that they now lie with strong angular unconformity below the Pliocene beds. The latter, ranging up to 1800 feet thick and including gypsum and salt beds as much as 100 feet thick locally, bear witness to continued deepening of the basins. The well-defined fault scarps, as well as historically dated faulting, prove that the

movements are still going on In résumé, this province came into existence through profound normal faulting that began in Miocene time, reached its climax during the Pliocene, and has continued to the present

**Stripping and Canyon Cutting in the Colorado Plateau.** The Colorado Plateau is remarkable for tabular plateaus, cliff-bound mesas, and deep canyons, all of the most impressive magnitude Gently dipping formations of Triassic, Jurassic, and Cretaceous age rise one

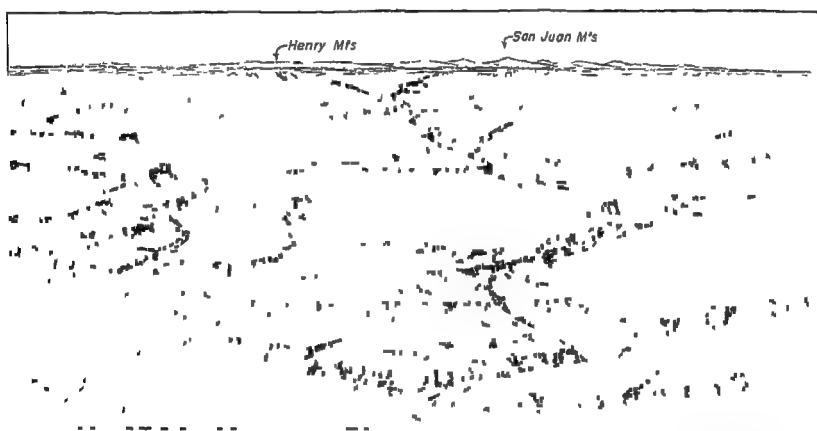



Fig 268 Aerial view of the Grand Canyon district, looking east-northeast across the mouth of the canyon where it cuts through Grand Wash Cliffs and enters the lower country to the west of the Colorado Plateau The Grand Canyon proper extends up to the mouth of the Little Colorado River, above which the gorge is called Marble Canyon as far as Echo Cliffs, and above that, Glen Canyon

above another in terraced plateaus bounded by unscalable cliffs many hundreds of feet in height (Fig 268) These cliffs are the receding edges of resistant formations, truncated during an Early Cenozoic erosion cycle, and their grandeur bears witness to the vast amount of stripping that the region has suffered since the end of the Cretaceous

The region was more or less extensively covered by Eocene sediments (Fig 269) like those of the Green River and San Juan basins, and since no Oligocene formations are present, it appears that by Oligocene time the area had a low relief and well-established exterior drainage

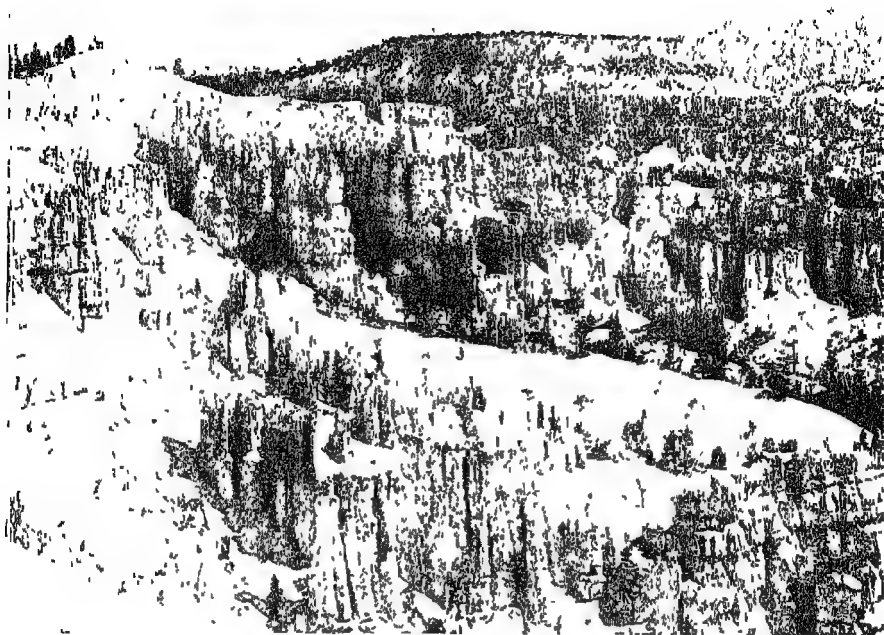
At some later date there was regional uplift with more or less profound normal faulting This started a new cycle of erosion that resulted in extensive degradation but left no later Cenozoic sediments within the region It is therefore difficult to date precisely the stages

NATIONAL PARK SERVICE

*Fig 269 Eocene (Wasatch) strata in the north rim of Bryce Canyon, Bryce Canyon National Park, Utah View along the rim from Sunrise Point, Boat Mountain in the middle background These Eocene beds form the Pink Cliffs of the Colorado Plateau (Fig 268)*

of uplift or to determine how many cycles of erosion are represented

The presence of Eocene beds unconformably overlying truncated folds in the Mesozoic formations (Fig 270) indicates that a large amount of the degradation and stripping had been accomplished during the interval between the Laramide uplift and the local beginning of Eocene deposition On the other hand, the Eocene beds mantled an old surface of low relief, hence the present ruggedness of the region has come into being during later Cenozoic time

The Grand Canyon proper is incised in a part of the area that was most uplifted, though it has since been reduced by erosion to a level 2000 or 3000 feet below the plateaus farther north The Grand Canyon district is, in fact, a broad, nearly flat-topped dome about 100 miles across, from which more than 6000 feet of Mesozoic strata has

been stripped (Fig 271) Over this dome the strata dip gently, but they are more abruptly bent down at its eastern margin in a pair of great monoclinal flexures The west side of the dome has broken down along a great normal fault, leaving the Grand Wash Cliffs facing westward toward the lower country of the Basin and Range Province

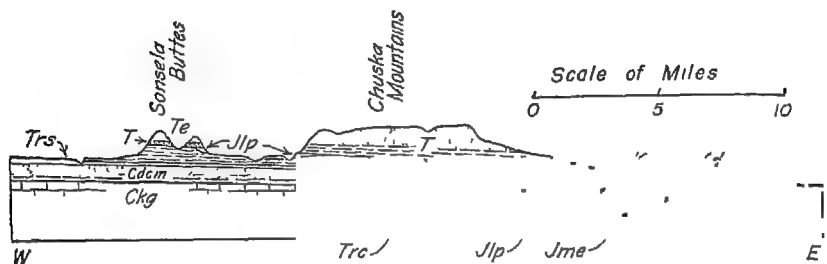



Fig 270 Section through the Chuska Mountains, northeastern Arizona, showing early Cenozoic (Eocene?) sediments (*T*) resting unconformably on truncated Cretaceous (*Kd*, *Km*, *Kmv*) and older formations in the Defiance monocline After H E Gregory, U S Geological Survey

Before the cutting of the canyon began, the stripping of this huge dome had reached almost its present stage and left the high cliffs of the region about as they are now Although these towered above the intervening benches with a relief of a few thousands of feet, the region as a whole was much nearer sealevel than at present The final uplift of the region led to a reorganization of the drainage, initiated the present Colorado River system, and started the canyon cycle

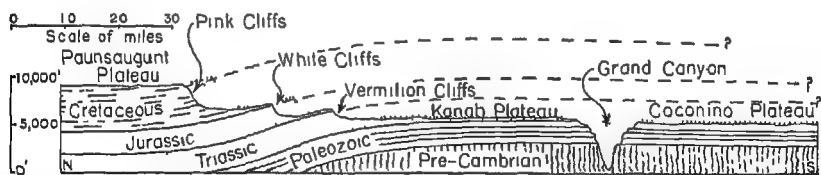



Fig 271 North-south section across the Grand Canyon region south of Kanab, Utah, showing relation of the present surface to the structure The base line is drawn at sealevel Dashed lines indicate the position Mesozoic formations would assume if the eroded portions were restored, dotted line indicates the profile before the last uplift, which initiated the cutting of the Grand Canyon

The date of this uplift can be determined west of the Grand Wash Cliffs where the river emerges from its canyon and crosses the Great Basin, flowing over Miocene beds that are known from their salt and gypsum deposits to have formed in arid basins without exterior drainage Obviously, the Colorado River did not exist, or at least did not

have its present course, in Miocene time Hence the great uplift of the plateau and the carving of the canyon are the work of Pliocene, Pleistocene, and Recent time [7]

**Building of the Columbia Plateau.** North of the Basin and Range Province, and occupying the area between the Northern Rockies and the Cascade Ranges (Fig 267) lies the Columbia Plateau, a vast upland built of Cenozoic basalt flows that cover an area of more than 200,000 square miles and reach a maximum thickness of over 5000 feet The total volume of the lava is estimated at 24,000 cubic miles For the most part it emerged through fissures in a very fluid condition and spread widely in sheets a few feet to a few tens of feet thick These flows sought the lowest places, filling the old valleys and encroaching on the flanks of hills and mountains In time the pre-basalt topography was buried, and a relatively flat basalt plain was constructed

The larger streams, such as Snake and Spokane rivers, have since cut through the lava flows in some places, especially near the eastern margin of the plateau, revealing a pre-basalt surface of considerable relief (at least 2500 feet), formed on schists, granites, and other pre-Cenozoic rocks

As the flows spread over this region, they interrupted the drainage, damming streams and giving rise to local lakes and swamps in which sediments accumulated, entombing plant and vertebrate remains Such fossiliferous deposits now locally interbedded with the lavas serve to date the eruptions A noteworthy example is the *Latah* formation exposed in the valley of Spokane River near Spokane, Washington Consisting of sands and clays and including much reworked volcanic ash, it has an exposed thickness of about 500 feet, but deep wells reveal 1500 feet of such beds with interbedded lava flows The deposit lies at the eastern margin of the Columbia Plateau and was formed in swamps and lakes created when the lava, flowing eastward, dammed the streams that flowed westward from the Rocky Mountain region in Idaho The Latah formation has yielded a large number of well-preserved Miocene plants

A similar deposit is the *Payette* formation exposed in the Snake River Valley on the Idaho-Oregon boundary about 250 miles south of Spokane It has yielded both plant and vertebrate fossils of Miocene date These and similar fossiliferous deposits interbedded with the flows indicate that the major part of the basalt eruption took place during Miocene time, though in some areas it continued into the Pliocene In fact, Snake River Valley (which forms a southeastern

lobe of the Columbia Plateau) is covered by black lavas of Pliocene and Pleistocene date in which the fresh appearance of spatter cones, like those of Craters of the Moon National Park, suggests activity within Recent time

During eruption, and also in later epochs, the Columbia Plateau was broken locally by normal faults, and was subjected to extensive, though gentle, warping, hence the plateau surface now varies from

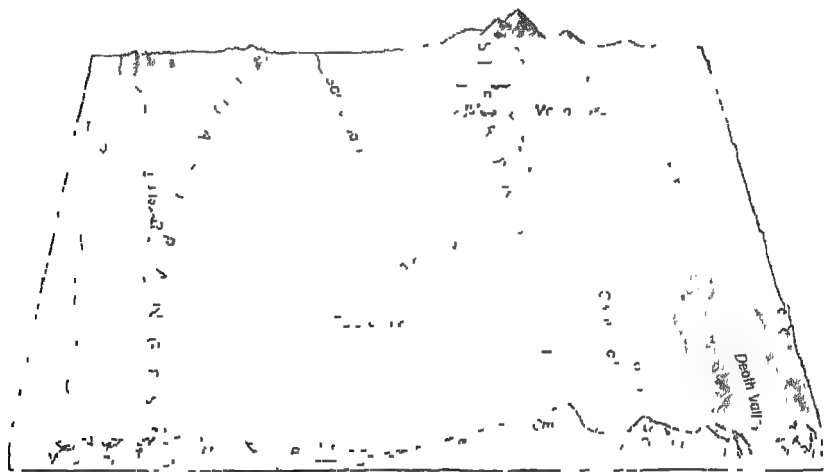



FIG 272 Idealized block diagram of a part of the Coast Ranges, the California trough, the Sierra Nevada, and the Basin and Range province The view is northward Length of section along front face, about 250 miles Vertical scale exaggerated about 50 times *Gm*, Mesozoic granite, *J*, Jurassic, *K*, Cretaceous, *M*, Miocene, *P*, Pliocene, *Ple*, Pleistocene, *Pl*, Lower Paleozoic, *Pu*, Upper Paleozoic

3000 feet to more than 8000 feet in elevation In part, the warping may have compensated for the extrusion of the great volume of molten rock from beneath the crust

## *The Pacific Border*

The Cenozoic history of the region west of the Basin and Range Province is extremely complex, and not yet fully understood As shown in Figs 267 and 272, it embraces two great mountain chains, separated by a series of large troughs The eastern chain consists of two independent units, the Sierra Nevada of California and the Cascade Mountains of Oregon and Washington, the western chain embraces the Coast Ranges The latter continue far to the north along the coast of British Columbia and have a counterpart to the

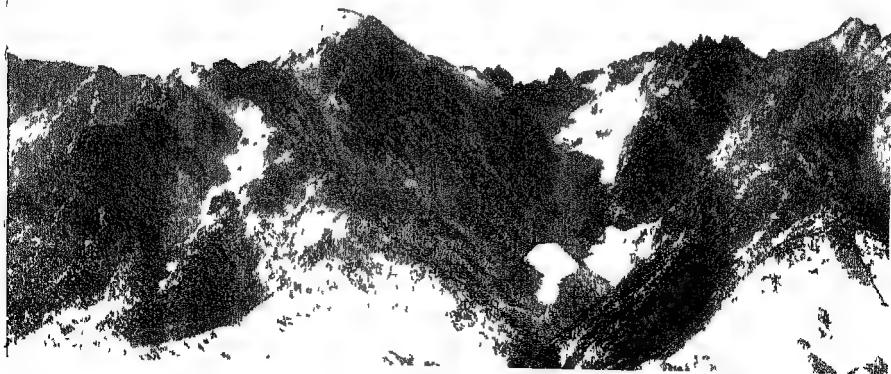
south in the peninsula of Lower California Between the Sierra Nevada and the Coast Ranges lies the California trough, a structural basin which has its counterparts farther north in the Puget Sound basin and to the south in the Gulf of California The history of these units is complexly interrelated

During Cenozoic time these structural troughs were depressed as the bordering mountains rose, and the sedimentary formations of this region are enormously thick, aggregating more than 50,000 feet The sea repeatedly invaded the California trough but seldom covered more than a small part of it, while nonmarine sediments were accumulating in other parts The Coast Range belt was in part submerged while undergoing complex deformation (both folding and faulting), with the result that relatively small embayments subsided to receive great depths of sediment from adjacent island masses that were rising

**Uplift of the Sierra Nevada** Figure 272 shows the structure and mutual relations of the Sierra Nevada, the California trough, and the Coast Ranges of California Although genetically related to the others, each has its distinctive form and structure

The Sierra Nevada represents part of a colossal fault block more than 100 miles wide and 300 or 400 miles long The eastern margin of this block has been uplifted to an elevation of about 13,000 feet (Fig 273), and its western edge depressed perhaps 25,000 feet below

F E MATTHES, U S GEOLOGICAL SURVEY

*Fig 273 East face of the Sierra Nevada, a great fault scarp 2 miles high Telephoto view westward from Owens Valley, California Compare Fig 272*

sealevel The uplifted part forms the Sierra Nevada, and the depressed half the California trough

The Sierra Nevada is sculptured from this single fault block of Jurassic and older rocks, the chief mass being a granite batholith All the structures within the range far antedate the Cenozoic. Its early Cenozoic history is obscure, but by Miocene time the region had been peneplaned Then began an uplift accompanied by faulting along its eastern border, which transformed it into a mountain range of moderate height Relative quiet ensued throughout Pliocene time, and the

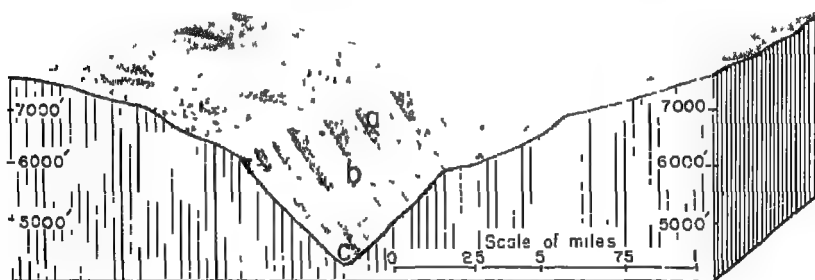



Fig 274 Cross-profile of Merced River Valley below Yosemite Valley, showing evidence of two stages of uplift *a*, profile of the old, broad valley, probably of late Miocene date when the region was still low, *b*, profile of the mountain valley stage (probably late Pliocene), cut after the first strong uplift and westward tilting of the Sierra block, *c*, canyon stage, cut during the Pleistocene in consequence of the last great uplift of the Sierra After F E Matthes, U S Geological Survey

westward-flowing streams then opened out broad valleys About the beginning of the Pleistocene, new uplift and westward tilting began, but the great uplift occurred near the middle of this epoch, after the second glacial age This elevation of several thousands of feet brought the mountains to their present altitude and started the westward-flowing streams cutting canyons within their broad valleys

Evidence of these distinct stages of uplift is found in (1) the cross-profiles of the valleys (Fig 274), and (2) the character of the deposits formed by these streams in the California trough

## Résumé of Cenozoic Orogeny and Volcanism The Cascadian Revolution

From the foregoing account, it must be clear that the Cenozoic was an age of great crustal disturbance and extraordinary volcanic activity in the western half of North America The Laramide thrusting died out irregularly during the long Eocene epoch, and the Oligocene was a

*Fig 275 Lava flows of the Absaroka Range present the appearance of horizontal strata from a distance Looking north across Shoshone Canyon about 25 miles west of Cody, Wyoming.*

time of comparative quiet during which most of the Cordilleran region was again reduced to lowlands

A new revolution began in the Miocene and continued intermittently to its culmination in the far-flung regional uplift of the Pleistocene This last great orogeny has been called the *Cascadian revolution* The Cascade Mountains were in the midst of the vast area of disturbance but actually comprised only a small part of it The movements were complex and diversified, but on the whole they were predominantly vertical movements (epeirogenic, not orogenic) accompanied by normal faulting In this we see a marked contrast with the Laramide revolution, which involved great horizontal forces and eventually produced enormous thrust faults and great folds During the Cascadian movements, folding was largely confined to the Coast Ranges and the Puget Sound basin In the former it probably resulted largely from the squeezing or wedging produced by differential subsidence of fault blocks In the Puget Sound area, where the thick Eocene beds are steeply upturned, the horizontal compression may have come from

the intrusion of a large granitic batholith into the northern part of the Cascade Mountains during Miocene time

Throughout the Cordilleran region the last movements were chiefly those of regional uplift in late Pliocene and Pleistocene time The greatest crustal movement in California evidently took place in middle

Fig 276 Profile section of Amethyst Cliff in Yellowstone Park, showing remains of eighteen successive forests, each killed and buried in turn by volcanic materials Section about 2000 feet thick

Pleistocene time, because the later deposits lie unconformably on the deformed early Pleistocene strata

In every respect the Pleistocene epoch is allied with the Pliocene, and if it were not for its extensive glaciation, the Pleistocene would probably never have been differentiated The Pleistocene is clearly a part of the Cenozoic era Whether the climax of orogeny and uplift is now past, only the future can tell, we are too close to it to judge

*Fig 277 Fossil tree trunks exposed in the face of Amethyst Cliff, Yellowstone Park Compare with Figs 276 and 16*

Volcanic activity occurred in the Cordilleran region during this era on a scale not approached at any other time since the remote Pre-Cambrian Volcanoes were active at the beginning of the era in most if not all of the western states Great basalt flows during the Eocene covered an area in western Washington and Oregon more extensive than all New England At the same time andesitic flows built up the Absaroka Range (Fig 275) and the plateau upon which Yellowstone Park is located, covering fault-block ranges of Mesozoic and older rocks to a depth of many hundreds of feet. Here the lavas overwhelmed forests at successive intervals of hundreds of years, as seen in Amethyst Cliff, where the stumps of eighteen successive forests stand petrified (Figs 276, 277)

Sedimentary beds interstratified with the lava and pyroclastics along the southern border of the Absaroka Plateau prove that volcanoes were

active there during middle and late Eocene as well as Oligocene time The older volcanics of the Yellowstone Park are also of Eocene age, and the younger ones chiefly Miocene, though present geysers and hot springs indicate that volcanic heat still smoulders

Many explosive volcanoes were active in Oligocene time, for the White River sediments are in considerable part reworked volcanic ash During this epoch, John Day basin in central Oregon was filled to a depth of 2000 to 3000 feet with reworked volcanic ash that has preserved an amazing array of fossil mammals

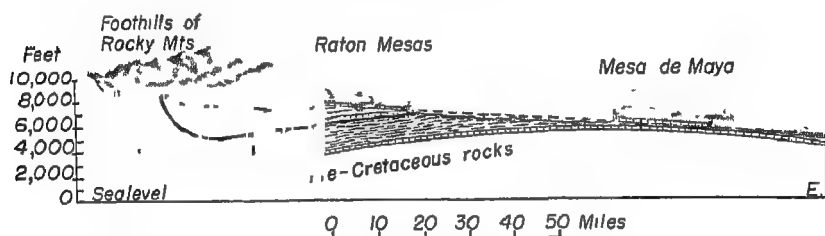



FIG 278 East-west section through Raton Mesas and Mesa de Maya, near Trinidad, Colorado The mesas are remnants of a Pleistocene lava flow that spread from the foothills of the Rockies almost to the Kansas line The lava rests on beveled Eocene strata, which in turn rest on Cretaceous *Eo*, Eocene, *K*, Cretaceous After Willis T Lee, U S Geological Survey

The Miocene was, however, the time of truly colossal volcanism At this time occurred most of the basic eruptions of the Columbia Plateau, Snake River Valley, and the Cascade Mountains, a vast field of basalt covering an area of more than 200,000 square miles At the same time a great field of volcanoes in southwestern Colorado built up the San Juan Mountain mass Volcanoes were scattered over the Basin and Range region and the Colorado Plateau, and there was extensive igneous activity in Mexico Igneous activity in the Black Hills of South Dakota gave rise to a remarkable series of laccoliths whose partly denuded forms are now striking features of the region

In many of these regions volcanism continued with decreased vigor through the Pliocene and into the Pleistocene, no fewer than 120 fields of volcanoes being known with cones that were still active in the Pleistocene Near Trinidad in the foothills of eastern Colorado there are impressive features of Cenozoic igneous activity Spanish Peaks are a pair of denuded majestic Eocene intrusives with a unique display of great radial dikes A short distance southeast of these lie Raton

Mesas and Mesa de Maya (Fig 278), which are remnants of Pleistocene basalt flows that spread eastward over the plains almost to the Kansas line

## Cenozoic Orogeny and Volcanism in Other Continents

The history of the Andean chain of South America paralleled that of the Rockies in many respects. Folded at the close of the Mesozoic, the Andes were extensively peneplaned during the earlier half of the Cenozoic and then, chiefly during Pliocene and Pleistocene time, were vertically elevated by several thousands of feet to their present height

The Alpine-Himalayan systems, stretching from western Europe to the East Indies, had a complex and spectacular Cenozoic history (Fig 279) The beginning of the Alps goes back to the Mesozoic, when a very broad geosyncline occupied by the greater ancestral Mediterranean (Tethys) spread over all southern Europe and eastward across the Himalayan region In Jurassic time horizontal compression from the south caused two or three great folds to rise out of this sea Although this marks the beginning of the Alpine structures, the region as a whole remained submerged during much of Cretaceous time At the close of the Cretaceous there was further compression and some uplift, and in the Eocene the first decided thrust, but marine waters returned between the rising geanticlinal folds and persisted widely until middle Oligocene time Then occurred the first great paroxysm of Alpine orogeny as the compression from the south caused great recumbent folds to rise as mountain arcs out of the sea, and to ride forward over the old foreland north of the geosyncline, where they piled up as a series of nappes (Fig 279, 3)

Before these great thrusts lay a lowland, now the Swiss Plateau Over this was spread, during late Oligocene and Miocene, a vast piedmont deposit (the *Molasse*) of sand and coarse gravel derived from the rising mountains Most of it is of freshwater deposition like the Cenozoic deposits east of the Rockies, but marine horizons show that the sea still had access to the northern border of the Alps as late as Miocene time In the Pliocene came further great thrusts from the south that caused the older nappes to ride out over the Molasse and buckled up the Jura folds that now form the northern front of the Alps This also gave a great regional uplift to the entire mass, an uplift that reached its culmination in the Pleistocene

The history thus sketched for the Alps is, in general, that of the Carpathians, the Dinaric Alps of Dalmatia, and the Himalayas. In the

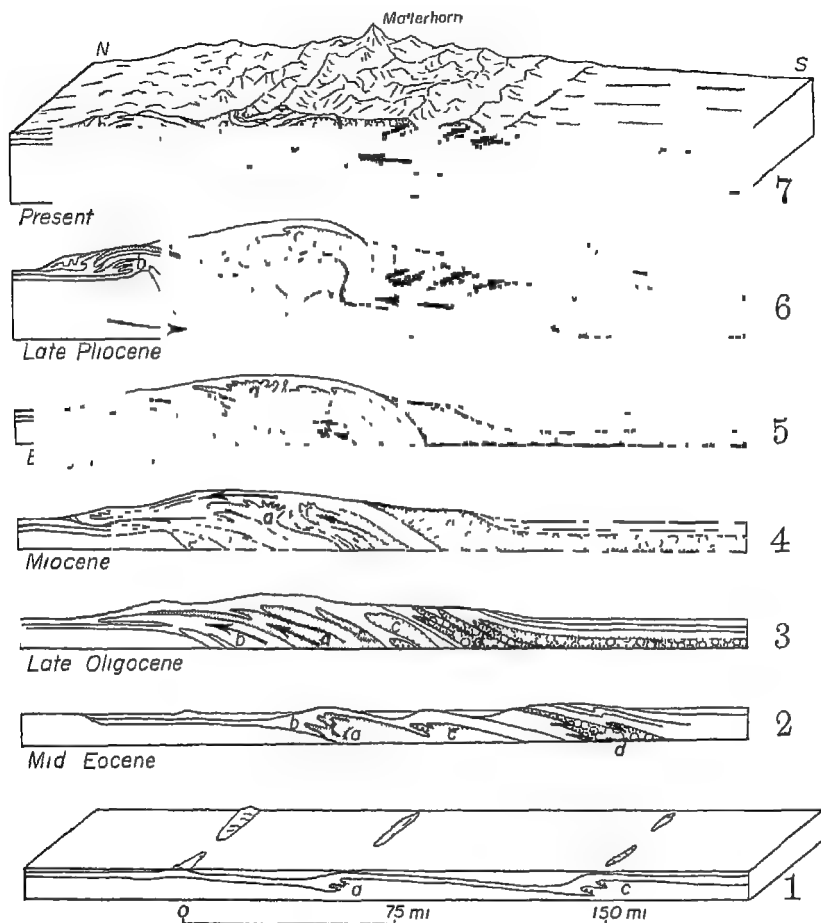



FIG 279 Development of the western Alps Adapted from a figure by Collet, after Argand Block 1 represents a belt across the Alpine region in late Mesozoic time when it was still largely covered by the Tethyan sea, block 7 shows a corresponding area in the modern Alps, and sections 2 to 6 show how the modern structure developed during Cenozoic time as a series of nappes were thrust one over another toward the north Finally, in late Pliocene time, underthrusting steepened the roots of the southern nappes and caused a series of thrusts toward the south, now seen in the Dinaric Alps *a*, Great St Bernard nappe, *b*, nappes of the Pre-Alps, *c*, Dent Blanche nappe, *d*, nappe of the southern Alps, *e*, Mont Blanc massive, *f*, Monta Rosa nappe.

southern one of the three ranges that make up the Himalayan system, marine Eocene formations now occur at an elevation of 20,000 feet, bearing witness to the tremendous uplift experienced by that region

since Early Cenozoic time. The foothills of the southern Himalayas are believed to have suffered an uplift of 6000 feet since the beginning of the middle Pleistocene.

Many countries also had volcanic activity during Cenozoic time. In Central America especially, and in Mexico, the Antillean islands, and the Andean Plateau, there were great outpourings of lava. The North Atlantic was also the scene of large basalt flows, now displayed in northern Ireland (Giant's Causeway), northwest Scotland, the Orkney Islands, the plateau of Iceland, and eastern Greenland. The great rift valleys of East Africa constituted another arena of great eruptions. Finally, during Pliocene and Pleistocene time, volcanic chains became active in the Mediterranean region and in Alaska, Japan, and the East Indies, completing the "Ring of Fire" around the Pacific.

## Cenozoic Climates

Fossil plants throw much light on the climate of Cenozoic time. The forest trees have come down to us with only trivial change since early Cenozoic time and probably have not changed appreciably their preferred habitat. Moreover, it is well known that most of them are restricted in their distribution by rainfall and temperature, each preferring a definite environment. Accordingly, the vegetation of a subtropical lowland like Florida has little in common with that of a desert basin, or with the forests of a temperate mountain slope, or with the subarctic barrens. Thus it is possible to infer the climatic conditions under which a Cenozoic flora lived.

A comprehensive study of such material throughout western North America[*] has shown a striking change of climate since early Cenozoic time. During the Eocene and Oligocene epochs subtropical types of trees, now restricted to moist lowlands, ranged widely over the United States and Europe. Palms and alligators were then common as far north as the Dakotas, suggesting a climate like that of modern Florida and Louisiana. At the same time a moist temperate forest existed in high northern latitudes, notably in Alaska, Greenland, Spitzbergen, and northern Siberia. It was dominated by the giant redwood and included such deciduous trees as the basswood, beech, chestnut, and elm. Even cycads, magnolias, and figs then lived in Alaska. The climate was not only milder and more humid, but also more uniform than now over the far western United States, evidently because the region was generally low and the mountains were

not lofty enough to interfere seriously with the moisture-bearing westerly winds

After Eocene time there was a slow but general southward migration of the various plant assemblages, indicating a gradual cooling of the climate that became more marked in Pliocene time and culminated in the Pleistocene glaciation Meanwhile, in Miocene and Pliocene time, the climate became more diversified in the western United States as the rising mountains intercepted the winds, producing moist western slopes and arid regions in their lee This diversity was not nearly so extreme or so widespread in Miocene time as it is today, though the salt and other precipitates entombed in the Miocene deposits of southern Nevada indicate rather intense local aridity in the basins then forming Even as late as early Pliocene time, however, a flora like that of southern California was still living in western Nevada (the Esmeralda flora), indicating a rainfall of 12 to 15 inches a year in a region where the present rainfall is only 4 inches The final uplift of the Cordilleran ranges in the late Pliocene and Pleistocene gave the intermont basins and the Great Plains their present degree of aridity

Mention should also be made of local evidence of cold climate at the very beginning of the era About the flanks of the San Juan Mountains in southwestern Colorado there is a deposit of tillite up to 100 feet thick (Ridgway tillite) lying unconformably on the Cretaceous and overlain by tuffs of Eocene date These glacial deposits are so distributed as to indicate a source in the crest of the mountains some 40 miles away The presence of such extensive valley glaciers in a region where now there are none clearly indicates that the snowfall was then vastly greater than now, or the average temperature was considerably lower, or else both conspired to produce glaciers Unfortunately, the tillite can not be more closely dated, but it probably was formed at the time of maximum uplift at the end of the Mesozoic era, or shortly thereafter The widespread plant evidence indicated above shows that by Eocene time warm temperate climate had spread as far north as the Arctic Circle

## Economic Resources

**Petroleum.** Two of the major American oil fields draw their production from Cenozoic rocks The Gulf Coast pools of Louisiana and southeast Texas are in small domes associated generally with stock-

like plugs of rock salt that have pressed up from below into Miocene sands and clays. The California oil fields likewise draw nearly all their oil from Miocene (over 30 per cent) and lower Pliocene (65 per cent) strata.

Although the greatest American oil fields are in Paleozoic or Mesozoic rocks, it is a very striking fact that nearly all the foreign fields are in Cenozoic formations. For example, the rich Baku fields of Russia produce from the Miocene, the Galician fields from the Eocene, Oligocene, and Miocene, the Rumanian fields from Oligocene to Pliocene, those of Burma, Sumatra, Java, and Japan from the Miocene, and those of the Persian Gulf chiefly from the Miocene.

**Coal.** Lignite occurs in the Eocene of the Gulf Coast but is not commercially exploited. In the Puget Sound region, however, the strong folding of the coal-bearing series has advanced the Eocene coals to a sub-bituminous rank. These coals are now being extensively used west of the Sierra Nevada and Cascade ranges. Their total production up to 1939 amounted to a little over 125,000,000 tons. In several of the coal fields of Montana and Wyoming the Fort Union formation is the chief producing horizon, and the reserves in these beds are extensive. In most parts of the world, Cenozoic coals are of lignite or low-grade sub-bituminous rank and therefore of little present value.

**Placer Gold.** As noted before, the placers, which yield about two-thirds of the annual gold of California, were formed during Cenozoic time by streams degrading the Mother Lode belt in the Sierra Nevada. Between the Gold Rush of 1849 and the year 1946, California had produced over $2,250,000,000 worth of gold.

**Metalliferous Veins.** The fabulous wealth of gold, silver, and copper so widely distributed throughout the Rocky Mountain region is for the most part a by-product of the intrusions of Cenozoic time. The mineral-bearing solutions of various sorts formed the vast copper deposits of Bingham, Utah, of Morenci, Arizona, and of Santa Rita, New Mexico. The silver of Park City, Utah, as well as of the great Comstock lode, Tonopah, and other localities in Nevada, was similarly formed in middle and later Cenozoic time. The gold of many of the spectacular mining camps of the West, such as Goldfield, Nevada, and Cripple Creek in the Rockies, had a similar date of origin.

Mexico, Central America, Peru, and Bolivia also provide notable examples of the great mineral wealth we owe to the crustal disturbances and intrusive activity of the Cenozoic.

**Diatomaceous Earth** Thick beds of pure diatom deposit are quarried from Miocene strata at Lompoc, California, and in Chesapeake Bay, for use chiefly as a sound- and heat-insulating material, as a base in polishing and scouring powders, and in various other ways The output in 1939 was 105,000 tons, valued in excess of $2,000,000

## References

[1] *Two Recent Wells in Coastal Plain of North Carolina*, by F M Swain Bulletin of the American Association of Petroleum Geologists, Vol 31, 1947, p 2056

[2] *Geology of Cameron and Vermilion Parishes*, by Henry Howe *et al* Louisiana Geological Survey, Bulletin 6, 1935

[3] *The Lower Miocene Mammal Fauna of Florida*, by T E White Bulletin of the Museum of Comparative Zoology, Vol 92, 1942, pp 1–49, pls 1–14

[4] *Additional Studies on Subsurface Stratigraphy of Atlantic Coastal States between New Jersey and Florida*, by H G Richards Bulletin of the American Association of Petroleum Geologists, Vol 32, 1948 (in press)

[5] *Relationship between Floras of Type Lance and Fort Union Formations*, by Erling Dorf Bulletin of the Geological Society of America, Vol 51, 1940, pp 213–236

*Foraminiferal Evidence for the Midway (Paleocene) Age of the Cannonball Formation in North Dakota*, by S K Fox and R J Ross, Jr Journal of Paleontology, Vol 16, 1942, pp 660–673

[6] *Eocene in North Dakota*, by William E Benson and Wilson M Laird Bulletin of the Geological Society of America, Vol 58, 1947, p 1166

[7] *How Old is the Colorado River?*, by Chester R Longwell American Journal of Science, Vol 244, 1946, pp 817–835

The principle accepted by Dr Longwell is that adopted, at his suggestion, in the previous edition of this book, which then led us to the conclusion that the cutting began after Pliocene time Since then, critical restudy of the vertebrate fossils in the Muddy Creek formation (youngest of the interior basin deposits cut into by the Colorado River) indicates that its age may be as old as Miocene instead of Pliocene (as previously believed)

[8] *Tertiary Forests and Continental History*, by Ralph W Chaney Bulletin of the Geological Society of America, Vol 51, 1940, pp 469–488

## Collateral Reading

*The Book of the National Parks*, by R S Yard 420 pages Charles Scribner's Sons, New York, 1919

*Physiography of the Western United States*, by N M Fenneman 534 pages McGraw-Hill Book Co, New York, 1931

An up to date account of the modern physiographic features which were produced during Cenozoic time in the western United States

*Guide Book of the Western United States*, by M R Campbell and others U S Geological Survey, Bulletins 611-614, 1915 Part A, The Northern Pacific Route, with a Side Trip to Yellowstone Park, Part B, The Overland Route, with a Side Trip to Yellowstone Park, Part C, The Santa Fe Route, with a Side Trip to the Grand Canyon of the Colorado, Part D, The Shasta Route and Coast Line

Written for the tourist who has an interest in geology Maps and running comments on all geologic features of interest within view of the routes followed

## Chapter 18

# ICE SCULPTURES THE FINAL SCENE

**The Pleistocene Ice Ages** Glacier ice has recently covered approximately one-third of the land surface of the Earth Its effects may be seen on every hand—in the serrate crests of mountains carved by valley glaciers, in the lake lands of Canada and Scandinavia, and in the drift plains of the north-central states and of north-central Europe Over large parts of the Northern Hemisphere, human culture and industry have been profoundly influenced by this fact, for the glaciers stripped away the soil from some regions, made swamp lands of others, deposited coarse boulder till in places, and over large areas spread the materials of an uncommonly deep, rich soil In such parts of the world, ice has given the final touches in the shaping of the modern landscape (Fig 280)

In view of the far-reaching influence of glaciation during this last geologic epoch, the Pleistocene has picturesquely been called *The Ice Age* Such a term, however, is a misnomer It disregards the fact that there was not one ice age but four, and that together they comprised but a small part of Pleistocene time In other respects this last epoch is closely allied to the Pliocene and earlier epochs of the era, and for that reason it was treated with the rest in the preceding chapter The long interglacial ages differed in no important respects from the preceding ages of the Pliocene Nevertheless, the glacial ages have such interest and importance that this special chapter is devoted to that one aspect of Pleistocene history.

### Extent of the Glaciation

**Distribution of Glacier Ice.** Three major ice sheets were present in the Northern Hemisphere (Fig 281) One of these, centered over Hudson Bay, occupied nearly all of Canada and spread southward into the United States (Fig 282), another centered over Scandinavia and reached the plains of north Germany and western Russia, and the third occupied part of Siberia Greenland was ice-capped then as now, and the Scandinavian Ice Sheet extended southward across the

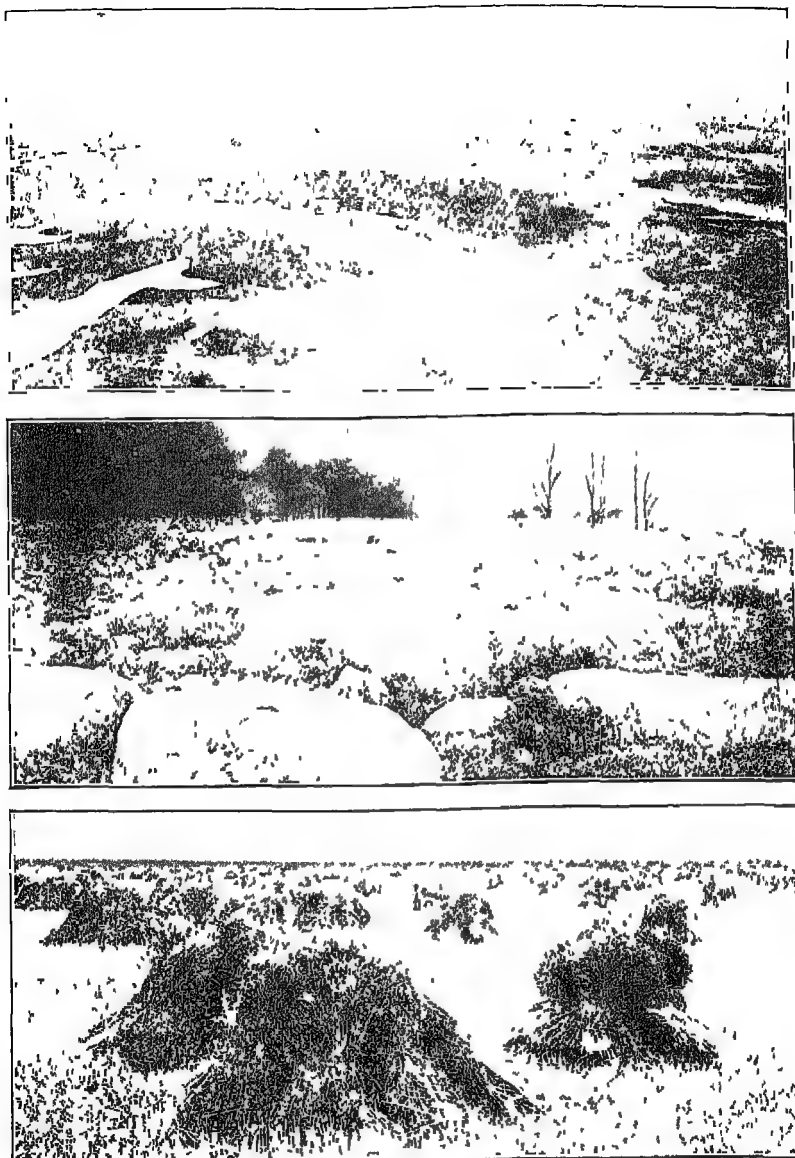



FIG 280 Economic and cultural effects of the Pleistocene glaciation in North America The aerial view of the lake country of Manitoba (top) shows the effect of glacial scour which removed the mantle and scooped out lake basins in solid rock The boulder field in New England (center) suggests how the clearing of the land was made a formidable task by coarse glacial drift The wheatlands of the Red River Valley in the Dakotas (bottom) are part of the floor of glacial Lake Agassiz Photographs from Royal Canadian Air Force, U S Geological Survey, and North Dakota Agricultural Experiment Station, respectively

floor of the North Sea and covered all of the British Isles except the southern edge of England In the Southern Hemisphere the Antarctic Continent undoubtedly was ice covered, and the highlands of Patagonia in South America and of South Island in New Zealand were heavily glaciated In addition, nearly all the lofty mountains of the world were capped by snow, and valley glaciers reached far below the present snowline

It is remarkable that the glacier ice covered great areas of lowland, and in central United States reached south of latitude 40° where, at present, summer temperatures of 100° F are not rare and where the regional snowline is at least 6000 feet above sealevel

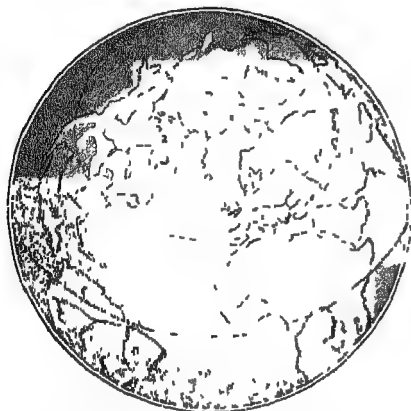



Fig 281 Pleistocene ice fields of the Northern Hemisphere

In the United States the higher parts of the Rocky Mountains were glaciated as far south as New Mexico (Fig 282), and the Sierra Nevada and Cascade ranges were also ice covered Glacier National Park in the Rockies and Yosemite Valley in the Sierra afford well-known illustrations of the work of these Pleistocene glaciers The Alps, the Himalayas, the Caucasus, the Pamir, and other lofty ranges of Eurasia carried great snowfields from which valley glaciers pushed out beyond the foothills onto the plains The higher parts of the Andes in South America also had extensive glaciers

The directions of ice movement in North America are indicated in Fig 282 These have been determined by mapping the end moraines, by plotting the direction of glacial striæ, and by noting the distribution in the drift of boulders of distinctive types of rock that could be traced back to their source The striking fact is that the ice did not spread southward from the polar region but radiated from centers in the latitude of Hudson Bay

Two quite distinct sheets can be distinguished, even though they formed parts of a single great field of ice The larger of these is the *Laurentide Ice Sheet*,[1] which centered over Hudson Bay and thence spread southward for a distance of some 1600 miles across the Great Lakes region into the Mississippi Valley It also spread westward up

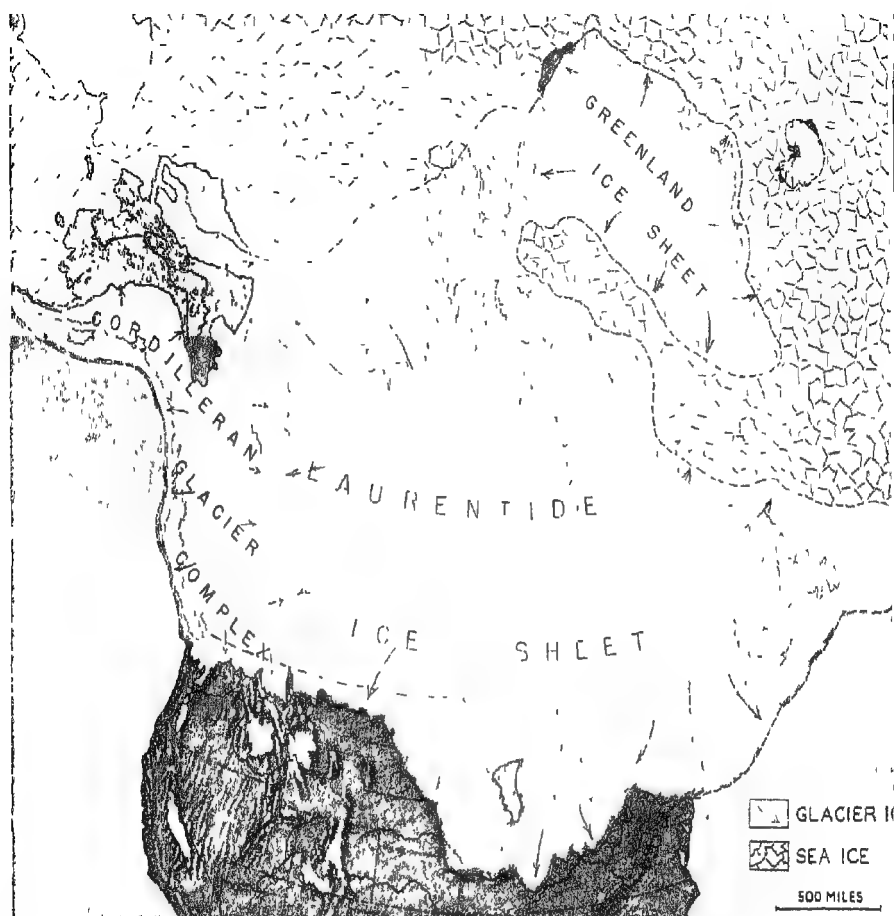



*Fig 282 Pleistocene glacier ice in North America Somewhat generalized to show maximum extent of the glaciation Arrows show generalized directions of glacier flow After Richard F Flint*

the long slope of the High Plains to the foothills of the Rockies and northward to the Arctic islands On the east and northeast the ice pushed out to sea and, at its maximum, may have been continuous with the Greenland Ice Sheet

It is probable that the Laurentide glacier ice first began to form over the mountains of eastern Labrador and Baffin Island[1] and from there grew westward until the center of accumulation was in the Hudson Bay area *

* The current belief that there were two independent centers of accumulation in this region, one west of Hudson Bay and another over Labrador, is not borne out by recent studies[1]

The second major ice sheet was the *Cordilleran Glacier Complex,* which occupied the mountainous region of western Canada. Ice probably began to form here as valley glaciers that radiated from the highest parts of the Coast Ranges and the Rockies. As these rivers of ice were extended to the lowlands, they developed into a complex of piedmont glaciers that not only spread over the foothills east of the Rockies and into the sea west of the Coast Ranges, but also converged to fill the broad basin between the two mountain systems. Up to this time the high ranges, intercepting the moisture-bearing winds, had been the chief centers of accumulation, and the spread of ice had been in part centripetal. As the intermont basin was filled, however, it became the chief center of accumulation from which movement radiated over both the Coast Ranges and the Rockies.

**Thickness of the Ice.** There is no direct evidence of the thickness attained at the center of the Laurentide Ice Sheet. The area of this Pleistocene sheet (4,800,000 square miles) was somewhat greater than the existing ice cap of the Antarctic Continent (4,000,000 square miles). The surface of the ice in Greenland and on the Antarctic Continent is about 10,000 feet above sealevel and appears almost flat except near the periphery, where it slopes off with increasing steepness to the wasting margins. During maximum glaciation the ice of the Laurentide sheet flowed westward up the long slope to the foothills of the Rockies, where it reached an elevation of about 4000 feet, and in its southward flow it covered the White Mountains (exceeding 5000 feet) and probably all of the Adirondacks (exceeding 4000 feet). Since ice moves in the direction toward which its surface slopes down, the altitude at the center of accumulation must have exceeded by a considerable amount the height of these features which the ice overrode near its periphery. Since the surface of the land about Hudson Bay is near sealevel (and was then probably depressed by a thousand feet or more under the weight of the ice), it is not unlikely that the glacier was at least 8000 to 10,000 feet thick over a large area.

## Glacial and Interglacial Ages

When erratic boulders strewn over the plains of northern Europe and over New England were recognized as the work of a former ice sheet, they were at first quite naturally attributed to a single glaciation. But as the study of the glacial deposits was carried westward into Illinois, Wisconsin, and Iowa, two distinct sheets of drift were

found at many places to be separated by old soil, beds of peat, or layers of till that had been leached and decayed (Fig 283) Here the uppermost drift, like that in New England, appeared fresh, but the buried drift sheet showed the effect of chemical decay and was obviously much the older Moreover, in places, the soil and peat or gravels between two such sheets of till included fossil wood and leaves and bones, indicating the existence of animals and plants of temperate

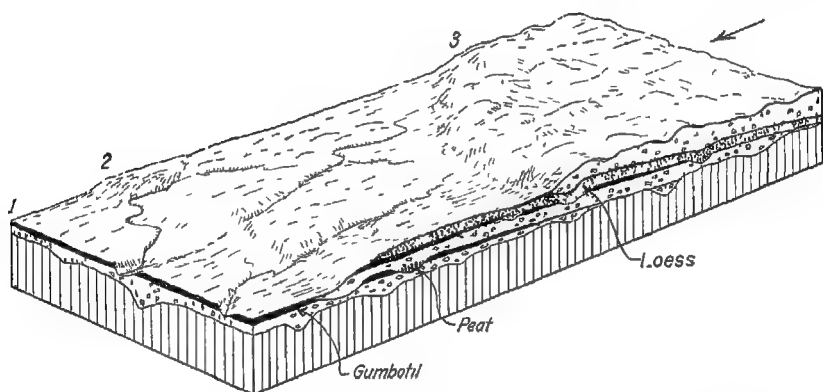



Fig 283 Idealized block diagram showing the relations of three imbricating drift sheets The block represents an area many miles across, and the vertical scale is exaggerated The first glaciation spread till across the entire region In the long interglacial age that followed, the surface of this first drift sheet was weathered to gumbotil (*black*) The second advance of the ice fell short of the first, and in a broad marginal belt the glacier ice overrode the older till, gumbotil, and peat deposits During a second interglacial age this till in turn suffered long weathering and developed a gumbotil In connection with the third glaciation, loess was spread widely over the older drift, and this in turn was overridden by the glacier ice which fell short of the middle of this area No gumbotil has yet formed on the youngest till

climate On this basis it came to be realized, about 1870, that two distinct advances of the ice had been separated by a relatively long interval of warm climate when forests grew over the older drift, and plants, such as the pawpaw, ranged considerably north of their present limit

By further application of the same principles, it was soon discovered that more than two glacial ages are recorded in the upper Mississippi Valley Meanwhile, similar discoveries were made in northern Europe, and now four glacial and three interglacial ages are established in both Europe and America These have been named for localities in which their deposits are typically developed, each glacial age in America bearing the name of a state Independent names have

been used in Europe, but it now appears probable that the glacial ages recognized on the two sides of the Atlantic correspond in time.

Records of the last glacial age are so abundant and so ready of access that much detail can be worked out, and in recent years four distinct glacial advances, separated by extensive recession, have been recognized as subages of the last or Wisconsin glacial age

**Implications of Pollen Analyses** An analysis of the pollen, abundantly preserved in peat associated with the glacial deposits, has recently added much to our understanding of the glacial history Since the pollen of each kind of forest tree is distinctive, a pollen analysis indicates quite clearly the composition of the surrounding vegetation in which any deposit of peat accumulated The modern species were extant during the whole of the Pleistocene and, then as now, were grouped into characteristic assemblages—for example, tundra plants, fir-spruce forest, tamarack, pine-mixed hardwood forest—each adapted to a distinct climatic environment Thus it is possible to infer, for example, that when certain interglacial deposits were forming at Toronto (the Don beds) the mean temperature was higher by 2° or 3° C than it is at present, and conversely, that when certain layers of peat were forming about Quincy, Illinois, the surrounding forests were of balsam fir, tamarack, pine, and birch, an assemblage that now lives at least 200 or 300 miles farther north

**Implications of Fossil Mammals** The land animals of both Europe and North America likewise migrated widely as the ice spread and waned During the height of glaciation, for example, the reindeer came as far south as southern New England, and the musk-ox ranged to Kentucky and Arkansas and Texas On the other hand, some of the interglacial deposits include both animals and plants that suggest a climate somewhat warmer than the present

It is clear, therefore, that the climate was colder than at present during the four glacial ages when ice covered far more than half of North America and approximately half of Europe, and that it was somewhat warmer than at present during at least some parts of the interglacial ages, and that the ice sheets then had retreated far to the north and probably had disappeared both from the mainland of North America and from Europe

## Stratigraphy of the Drift

The time represented by the existence of one of the continental ice sheets described above is a *glacial age,* and the time that elapsed be-

tween two of these is an *interglacial age* These are the major *time* units of the glacial epoch, and the corresponding stratigraphic unit is a *stage* Thus, the deposits formed during the Wisconsin glacial age constitute the *Wisconsin stage,* and those formed during the Sangamon interglacial age constitute the *Sangamon stage*

Figure 284 shows the distribution of the four drift sheets Their stratigraphic relations are further illustrated by Figs 283 and 285

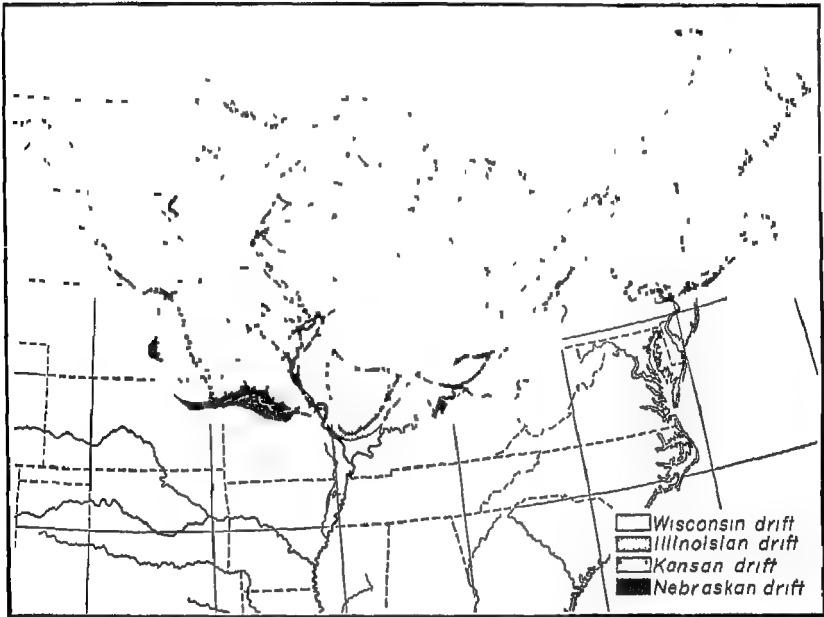



FIG 284 Map showing the southern limit of glacial drift in the United States Note that in the Mississippi Valley the older drift sheets extend farther south than the youngest, and here four sheets are differentiated After Richard F Flint

The *Wisconsin stage* is the uppermost drift sheet and is the one most easily mapped and the best understood For this reason it will be described first, and the older sheets will follow in turn, thus reversing the actual historical sequence The end moraines of the Wisconsin stage loop across the Central Lowland in festoons that outline the great southern lobes of the ice Its surface still retains the characteristic features of a glacial deposit—the swells and swales of the end moraines and the broad undulations and lakes and swamps of the ground moraine, locally diversified by drumlins It has suffered only slight chemical change during the few thousands of years since the

ice wasted away. Although a thin soil has formed over it and peat has accumulated extensively in the lakes and swales, chemical decay, even in fine materials, is limited to slight leaching to an average depth of 2 or 3 feet, and most of the boulders are as fresh as quarried stone. Along the main streams it has been partly removed, but elsewhere it has undergone but slight erosion. Outwash plains and valley trains beyond the end moraines are still easily recognized.

In New England the Wisconsin ice sheet flowed out beyond the present coastline (then dry land), largely destroying or concealing any marks of earlier glaciation, and there glacial studies are concerned almost exclusively with the Wisconsin drift. In the lowlands of the Ohio-Missouri River basins, on the contrary, the Wisconsin ice fell short of the earlier advances, and there the several known Pleistocene stages form an imbricated succession, as suggested in Fig. 283, and each in turn can be studied.

The *Illinoian stage* is known chiefly in Illinois, southern Indiana, and central Ohio, where it is not covered by Wisconsin drift, but it is exposed also in smaller areas in Wisconsin and Pennsylvania and New Jersey. Unlike the Wisconsin till, which is largely composed of sand, gravel, and boulders, the Illinoian till is chiefly made of silt and clay. Its surface retains traces of morainic topography, but mass-wasting of swells and deposition in swales have softened the relief.

Overlying the Illinoian till are materials that must be referred to the third interglacial (Sangamon) stage. These include the leached and decayed zone at the top of the till, numerous deposits of peat and of stratified sand and gravel, and a sheet of loess. In contrast to the freshness of the Wisconsin drift, the Illinoian till has a zone of oxidation that extends from 10 to 25 feet deep and a zone of gumbotil averaging 4 feet thick, even where it is overlain by fresh Wisconsin drift. *Gumbotil* is a dark sticky subsoil so named because it is a product of the chemical weathering of till. The presence of such material under the Wisconsin drift, where it has been protected since the beginning of the Wisconsin age, proves, of course, that the chemical decay was experienced by the Illinoian till during the Sangamon interglacial age. Also belonging to this last interglacial age is a widespread layer of loess (the Loveland loess of Nebraska and the Sangamon of Illinois). Pollen in a bed of peat preserved at Wapello, Iowa, records vegetation identical with that now inhabiting the area, suggesting that while this peat was forming the climate in Iowa was like the present.

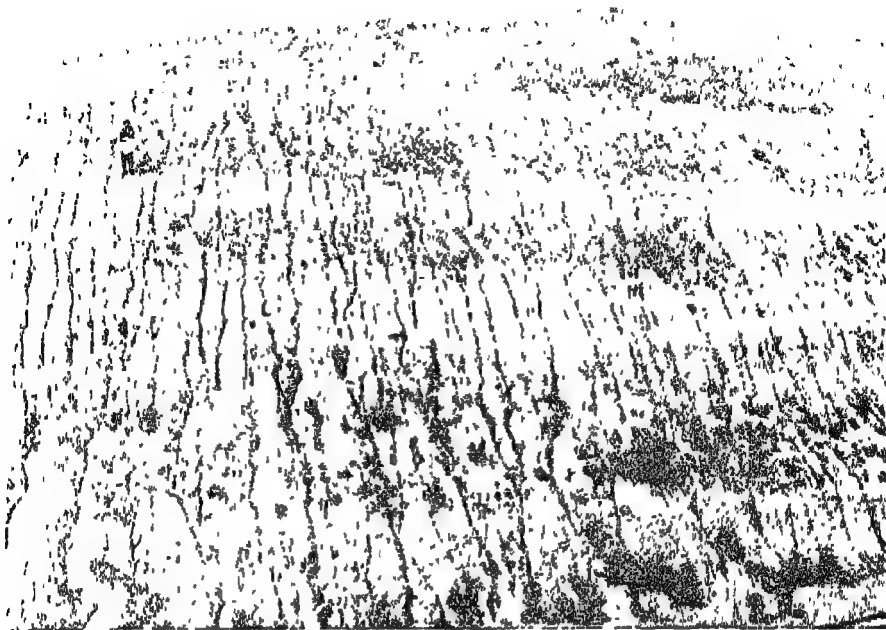



*Fig 285 Superposed sheets of till with gumbotil and loess exposed in a railroad cut southwest of Rhodes, Iowa The scale is indicated by the man at the left above*

The *Kansan stage* is represented by a sheet of till that is widely exposed in Iowa, northern Missouri, and northeastern Kansas, where it averages about 50 feet in thickness East of the Mississippi River it is known in places beneath the younger sheets of drift

During the second interglacial (Yarmouth) age, the surface of the Kansan till was deeply leached and decayed, and a layer of gumbotil was formed with an average thickness of 11 feet In places the till is covered with gravel beds, representing outwash, that are so deeply decayed that granite boulders commonly crumble and fall to pieces when struck with a hammer The Kansan till is also widely covered with a layer of loess (Fig 285) Beds of peat found at several places between the Kansan and Illinoian tills have yielded the pollen of forests of balsam fir, pine, and tamarack, suggesting a climate somewhat cooler than the present It is not known, however, what part of the long interglacial age they represent

The *Nebraskan* drift had approximately the same distribution as the Kansan, and its exposures are very limited, but it lies buried be-

neath most of the area mapped as Kansan It was a thick sheet of till spread over an irregularly eroded preglacial surface and averaging more than 100 feet in thickness

Overlying the Nebraskan till are deposits of the first interglacial (Aftonian) stage These include a layer of gumbotil averaging 8 feet thick, and scattered deposits of peat sandwiched between Nebraskan and Kansan till Pollen analyses from five such deposits in Iowa indicate at first a long time when the region was occupied by conifer forests, suggesting climate cooler than the present, then a landscape covered with grasses, indicating long endurance of a climate like the present, and finally a return of conifer forests and cooler climate as the Kansan glacial age approached

## Duration of the Ice Ages

Much ingenuity has been devoted to attempts to establish an absolute time scale for this last geologic epoch, one in which events could be dated in years Current results are indicated in the table on p 451, but it must be confessed that the age calculations involve a large degree of probable error and in part are highly subjective Such figures are, therefore, only tentative estimates

**Estimates of Postglacial Time.** Nearly all attempts to measure the length of Pleistocene time involve two steps first, measuring the length of "postglacial" time and, second, with this as a yardstick, estimating the relative length of each of the interglacial ages Two chief criteria have been invoked to measure "postglacial" time, one the rate of recession of postglacial waterfalls and the other the bodies of varved silt and clay formed in proglacial lakes during the recession of the last ice sheet.

The Falls of St Anthony in the Mississippi River at Minneapolis will serve to illustrate the first method of calculation Below the falls, and extending nearly 7 miles to Fort Snelling, there is a gorge 75 to 100 feet deep and about a quarter of a mile wide, produced by the recession of the falls It can be demonstrated that the cutting of this gorge began when the ice margin, during the last deglaciation, stood near the position indicated in Fig 286 In nearly 250 years after the falls were first observed by white men, their recession upstream averaged 2 44 feet per year At this rate, 15,000 years were required to cut the postglacial gorge

There is good reason for believing that the cutting of this gorge began at about the stage of deglaciation represented in Fig 286 In

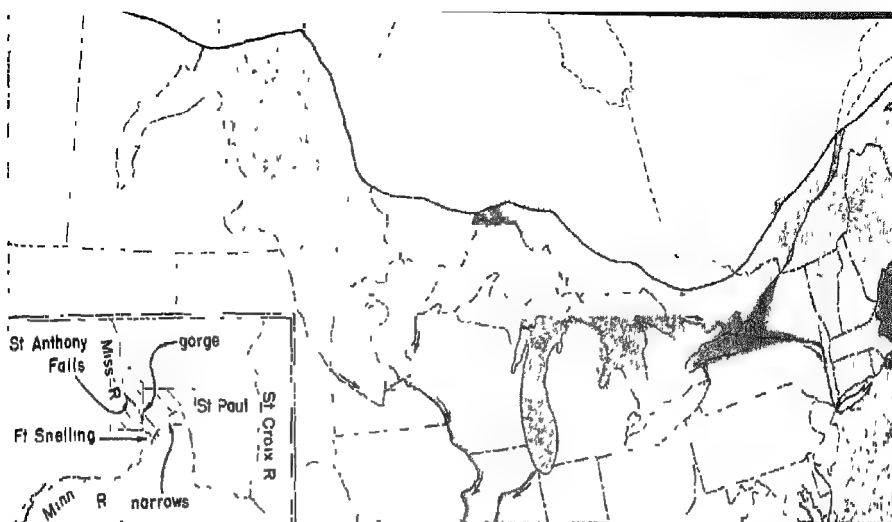



*Fig 286 St Anthony Falls and their postglacial history, showing position of the ice front and regional drainage relations as they existed when the cutting of the gorge below the falls began Details of the area about the falls are shown in the inset, in which buried preglacial channels are indicated in white and modern valleys in dark gray Based on data from Leverett and Taylor and from G M Schwartz*

preglacial time the Mississippi had cut a wide valley, its main trunk following approximately the course of the present Minnesota River above Fort Snelling The last glaciation filled all preglacial valleys with drift, and, when the ice melted back, the streams at first wandered over the surface of the drift, eventually incising themselves in new valleys As Minnesota was exposed, three main streams, the St Croix, the upper Mississippi, and the Minnesota, united near St Paul Cutting down through the drift, the trunk stream discovered the old preglacial valley just below St Paul (see inset of Fig 286) and proceeded to remove the loose fill below this point with relative ease. But from St Paul to a point just south of Fort Snelling the new stream was superposed upon the old upland of horizontal limestone beds Here its downcutting was greatly retarded, and, as it plunged from the surface of the limestone into the old valley, a falls was initiated that gradually migrated upstream until it again cut through into the buried preglacial valley a short distance southwest of Fort Snelling The recession of this great falls produced the narrows in the valley at St Paul, which are therefore obviously postglacial

For a time after deglaciation of the region around Minneapolis, all three stream branches carried great volumes of meltwater, but after the ice margin had reached the Canadian border, the drainage through the upper Mississippi diminished to something like its present volume. That of the Minnesota River, on the contrary, increased greatly as it became the outlet of the vast glacial Lake Agassiz, which formed over the Red River Valley while the ice still prevented drainage to the north. Thus, until the disappearance of Lake Agassiz, the stream we now know as the upper Mississippi was but a second-rate tributary to a great glacial stream that followed the present valley of the Minnesota River above St. Paul. The cutting of the narrows at St. Paul was chiefly the work of this great glacial stream and was accomplished while Lake Agassiz was discharging the meltwater from a great area of the ice. This gives us the clue to the position of the ice margin when the postglacial narrows at St. Paul were cut.

After the great falls in the glacial Minnesota River had receded past the mouth of the Mississippi tributary, the latter plunged from its limestone bed into the new valley and thus initiated the Falls of St. Anthony.

Unhappily for this calculation, however, a comparison of maps, sketches, and descriptions made since 1680 shows that the rate of recession has accelerated greatly during the period of observation. This is probably due to the fact that the Plattville limestone, which holds up the lip of the falls, thins upstream in the vicinity of the present falls. It appears evident, then, that the average rate of recession has been less than 2.44 feet per year, that the cutting of the gorge may have required more than 15,000 years, and that the probable error in the rate of recession may be great. Furthermore, we have been attempting merely to measure the length of time since the ice front stood at the position indicated in Fig. 286. It had already retreated some 700 miles from its farthest advance in Iowa, and there is no objective basis for determining the time involved in that retreat. A figure of 10,000 years has been postulated, making the total time 25,000 years since the ice front was in Iowa, but 10,000 years is a highly subjective inference.

A quite different approach to the measurement of postglacial time involves the study of varved silt and clay. The strikingly banded appearance of such deposits (Fig. 287) is due to a regular alternation of thin laminæ of silt (normally light in color) and of fine clay (normally darker). The Swedish geologist DeGeer discovered that such lamination is due to the special conditions that exist in proglacial

lakes During the summer months meltwater bears fine sediment in suspension, giving the water a milky, turbid appearance Currents and waves spread this turbid water, from which the coarser particles gradually settle to form a layer of silt on the lake floor When winter comes, the meltwater ceases to flow and the lake freezes over Then for some months, while the water is free of disturbance, even the col-

*R F Flint*

FIG 287 Varve clay from a glacial lake bed at South Hadley, Massachusetts At the right, a small detail, natural size, showing the gradation of the light gray, summer layers upward into the dark, winter layers

loidal particles of sediment settle slowly to form a layer of fine unctuous clay With the return of summer a new layer of silt forms over the previous winter's deposit Thus the paired layers of silt and clay, like growth rings in trees, record actual years of time, and it is a simple matter to count the layers and determine how many years were required for the formation of a deposit of varve clay

Of course, no single proglacial lake existed throughout the time involved in the shrinkage of the ice sheet, but DeGeer discovered an ingenious way of matching the bands in contemporaneous deposits of different lakes or in different outcrops, and thus was able to piece together many of the fragments of the record Lakes tend to form about the margins of a melting ice sheet, occupying either depressions

behind moraines or inequalities in the rock floor where the ground moraine is thin, and thus probably much of the time represented by deglaciation was recorded in varved sediments in one place or another. DeGeer pieced together the records of about 1500 outcrops lying between the southern tip of the Scandinavian peninsula and the modern proglacial lakes in central Sweden, and on this basis inferred that the shrinking ice exposed southern Sweden about 13,500 years ago. The ice margin lay in the plains of southern Germany during the maximum glaciation, and it has been impossible to find varved deposits to measure the duration of the recession from that limit to southern Sweden, but obviously it was several thousands of years. Recent estimates, based in part on DeGeer's work, place the date of maximum expansion of the last glaciation in Europe at about 35,000 years ago, but such estimates rest on no objective data and are obviously little more than guesses.

Recently the discovery of the significance of the ratio of two isotopes of Carbon ($C_{12}$ and $C_{14}$) in Pleistocene fossil wood has given an entirely new and dependable criterion of age. On this basis the last (Mankato) advance of the ice occurred in Wisconsin about 11,000 years ago.

**Estimates of a Pleistocene Time Scale.** There is no direct method of determining the length of the interglacial ages, and estimates of their duration are based upon a comparison of the weathering and decay of the older tills. For example, the Wisconsin till is almost fresh, showing but slight leaching in the upper 2 or 3 feet, whereas the Illinoian is deeply leached and has developed a gumbotil about 5 feet thick. It is certain that this long decay took place before the Wisconsin glaciation, because the last sheet of till has protected the buried drift from weathering. Obviously the Sangamon interglacial age was several times longer than all postglacial time. The Kansan drift is even more deeply weathered, and its gumbotil is about 11 feet thick. Its boulders also have been weakened by long decay. The underlying Nebraskan drift has a somewhat thinner gumbotil, and the first interglacial age was somewhat shorter than the second. Although there is no dependable criterion for the comparison, it is the judgment of the most profound students of glacial deposits that the Sangamon interval was not less than five times the length of the postglacial age, the Yarmouth not less than twelve times, and the Aftonian about eight times. The resulting estimates are 135,000, 310,000, and 200,000 years, respectively. To these must be added the quite uncertain duration of the several glacial ages, giving a total duration for the Pleistocene epoch estimated roughly at a million years. There

is now hope that a study of the radium concentration in sediments on the sea floor will give us an absolute chronology for the last 300,000 years or so[2]

Current estimates of glacial dates are indicated in the following table of Pleistocene chronology by Flint

CALENDAR OF PLEISTOCENE TIME

| Epochs (of Time) Series (of Deposits) | Ages (of Time) Stages (of Deposits) | Subages (of Time) Substages (of Deposits) | Duration in Years (Estimates in Roman type, guesses in *italics*) | Estimated Time Elapsed to Present |
|---|---|---|---|---|
| Pleistocene epoch | Wisconsin Glacial | Mankato<br>Cary<br>Tazewell<br>Iowan | 25,000<br>10,000<br>10,000<br>10,000 | 25,000<br>35,000<br>45,000<br>55,000 |
| | Sangamon Interglacial | | 135,000 | 190,000 |
| | Illinoian Glacial | | *100,000* | 290,000 |
| | Yarmouth Interglacial | | 310,000 | 600,000 |
| | Kansan Glacial | | *100,000* | 700,000 |
| | Aftonian Interglacial | | 200,000 | 900,000 |
| | Nebraskan Glacial | | *100,000* | 1,000,000 |
| Pliocene epoch | | | | |

**Fluctuations of Sealevel** If the modern ice sheets of Greenland and the Antarctic Continent were melted, sealevel would rise, it is estimated, by as much as 100 feet, drowning the low coastal plains and transforming the lower courses of many streams into estuaries But if, on the contrary, the former great Pleistocene ice sheets were restored, the water thus withdrawn from the oceans and piled up on the lands would lower sealevel by 300 feet or more, shifting the shoreline seaward almost to the present 50-fathom line

There is clear evidence that such striking fluctuations of sealevel have taken place repeatedly since the beginning of the Pleistocene. During times of maximum glaciation, streams were extended across the exposed parts of the continental shelves, cutting valleys that are now submerged. In subtropical regions the reduced temperatures at the same time inhibited the growth of corals and permitted the waves to cut wide benches about oceanic islands and along exposed coasts. These benches have since been transformed into lagoons by the growth of barrier reefs along their margins as the sealevel rose. Some of the low wave-cut benches extensively preserved along the modern coasts may have been cut during interglacial ages when the ice sheets of Greenland and the Antarctic Continent were reduced and the sealevel stood higher than now.

The lowering of sealevel by 300 feet or more made dry land out of extensive areas of shallow sea and permitted migrations of land animals and plants that would now be impossible. England, for example, was united to the continent of Europe, so that the hippopotamus crossed the channel from France, and Borneo and Sumatra in the East Indies were a part of Asia, so that elephants, rhinoceroses, and other large mammals crossed the lowlands now submerged to form the floor of the Java and Sunda seas. Alaska and Siberia were also united by land, and the woolly mammoth crossed freely.

**Depression of the Ice-Covered Regions.** The ice caps that formed over Canada and Scandinavia were loads too great for the Earth's crust to support, and both regions sagged to the extent of many hundreds of feet at the very least. The depression was greatest where the ice was thickest, and in Canada it amounted to about a thousand feet in the area midway between the Great Lakes and James Bay. Since the ice wasted away, there has been substantial recovery, but before the upwarping took place, unmistakable records of the depression had been made in the form of beach ridges and wave-cut cliffs along the shores of vast proglacial lakes. These features, still recognizable, have been studied and mapped. One of them, marking the shore of glacial Lake Algonquin, is at an elevation of nearly 600 feet in west-central Michigan but rises to 935 feet at Sault Ste. Marie, 1150 feet at North Bay on Lake Huron, and apparently 1450 or 1500 feet at Goudreau Lake, 150 miles north of Sault Ste. Marie. This indicates a relative upwarp in postglacial time of 335, 550, and 850–900 feet, respectively, at the places named. The beaches of glacial Lake Agassiz (Fig. 286) in Manitoba show a similar upwarp toward the north amounting to at least 400 feet.

When the ice had wasted back far enough to free the St Lawrence Valley, the region was still so much depressed that marine water spread up the St Lawrence and into the Champlain Valley and probably into Lake Ontario, depositing a layer of blue clay with abundant shells of an arctic molluscan fauna This is the *Leda clay*, so called for a small but characteristic clam The recent discovery of two whale skeletons in bogs above the glacial deposits in Michigan indicates that for a brief time the sea was directly connected with the Pleistocene Great Lakes Marine shells and the bones of whales have been found in the Leda clays at least 500 feet above sealevel at the Vermont-Quebec boundary, nearly but not quite up to the Lake Ontario level at Kingston, and at about 600 feet in the Montreal-Quebec area The postglacial upwarp thus indicated is probably a minimum measure of the depression caused by the ice

**Glacial Erosion beneath the Ice Sheets** Radial movement of the Laurentide Ice Sheet stripped the mantle from a vast area of the Canadian Shield, leaving a floor of fresh bedrock scoured unevenly into thousands of shallow basins now occupied by lakes (Fig 280) The areas of bare rock showing through the scant cover of vegetation advertise the fact that the glaciation cost eastern Canada one of her greatest resources, the soil that had formed during the ages before the coming of the ice

Over a broad peripheral belt the ice spread its load of drift, filling pre-existing valleys with till, and smoothing the inequalities of the surface Thus the material stripped wholesale from the southern part of Canada was spread widely over the north-central United States to form the source of a very deep rich soil

**Drainage Changes.** As the ice sheets advanced southward into the United States, all north-flowing streams were blocked, and the meltwater was turned along the margin of the ice until it spilled over divides into south-flowing streams The channels thus formed at the maximum advance were in many places held after the disappearance of the ice, because former channels were obliterated by the drift The present course of the Ohio River is due, thus, to the welding together of many short tributaries to different streams, several of which had flowed northward in preglacial times (Fig 288) The course of the Missouri was also locally shifted to the southwest For this reason the Ohio and Missouri rivers record rather closely the limits attained by the ice sheets at their greatest extent

**Development of the Great Lakes** Before the glaciations the basins now occupied by the Great Lakes were probably broad lowlands

eroded by preglacial streams The Lake Superior basin marks an ancient synclinal structure occupied by relatively weak rocks in which a broad valley had been eroded, the other lake basins were carved on the outcrops of relatively weak rocks in front of or between the cuestas that had been sculptured by Cenozoic erosion of the Paleozoic formations overlapping on the Canadian Shield. These lowlands were

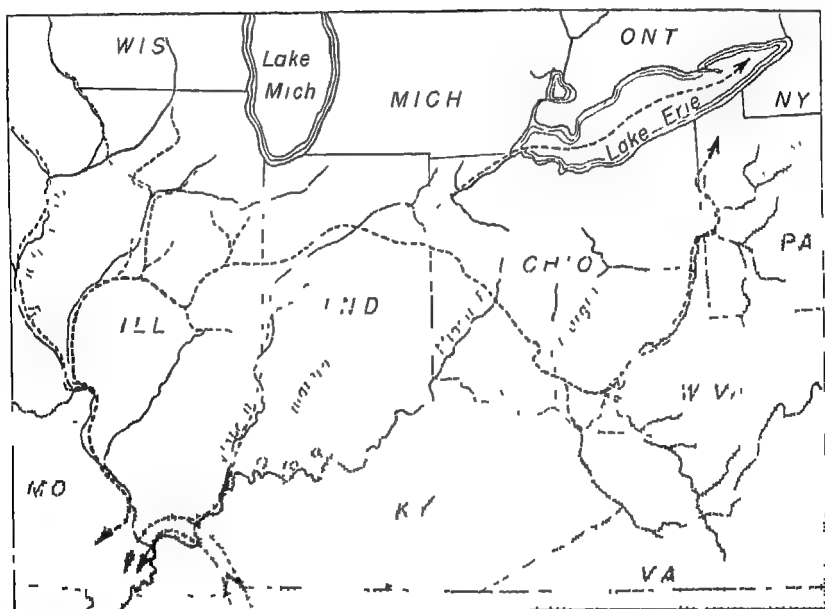



Fig 288 Drainage changes in the Ohio and Mississippi river basins due to glaciation Preglacial drainage courses are shown in broken lines Adapted from R F Flint (1947)

drained by streams, some of which probably flowed southward through gaps in the cuestas, while others may have flowed northeastward into the St Lawrence As the successive ice sheets flowed outward, they filled these lowlands with thick ice lobes that gouged and deepened them, especially where, as in the case of Lakes Superior and Michigan, the axis of the depression nearly coincided with the directions of ice flow

South of the Great Lakes basins, on the other hand, the ice sheets spread a thick mantle of drift that filled and deeply buried the old valleys for scores of miles As a result, when the ice later retreated northward over the Great Lakes region, its front became deeply lobate, with a great tongue of ice occupying each of the deepened basins

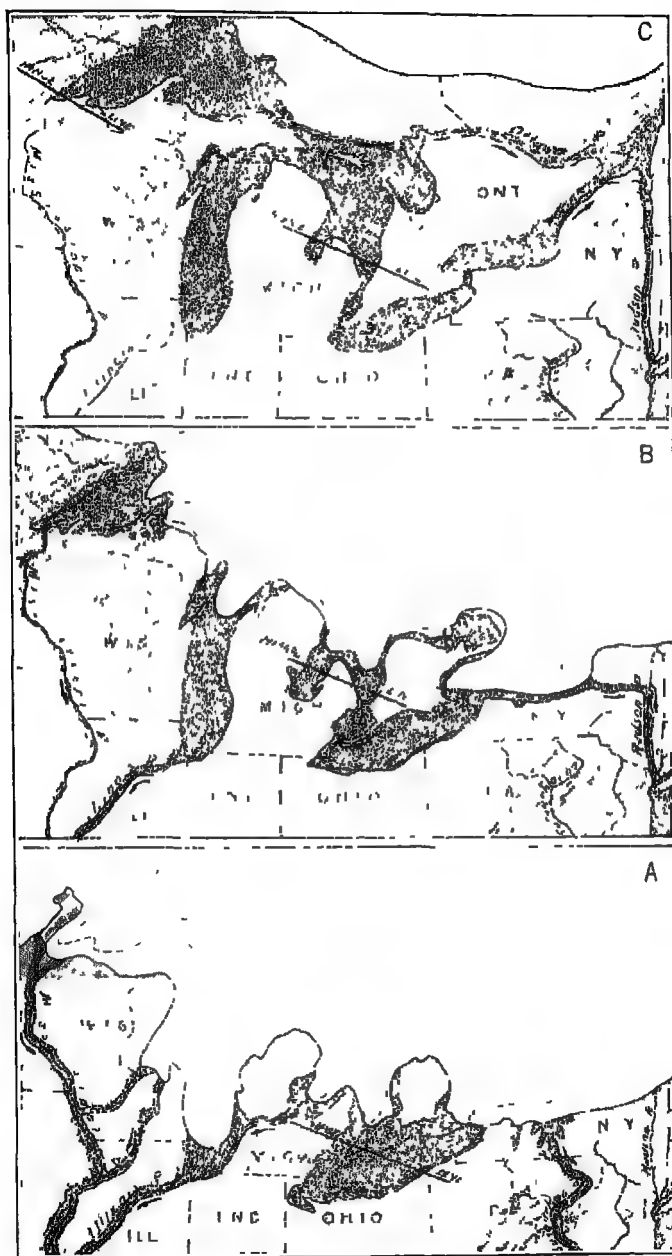



FIG 289 Three stages in the development of the Great Lakes as the last ice sheets wasted away Adapted from Leverett and Taylor, U S Geological Survey

As these shrank back, lakes formed about the end of each of the lobes, the water standing at the level of the lowest spillway that would lead southward across the drift into the Mississippi drainage system At first the overflow was southward via both the Wabash and Illinois rivers, but somewhat later it was westward along the front of the ice to the vicinity of Chicago (Fig 289*A*), where an outlet was found via the Illinois River Eventually the Mohawk Valley in New York was freed of ice, and thus opened a much lower spillway whereby the drainage was for a time diverted east into the Hudson River (Fig 289*B*) At a still later stage the St Lawrence Valley was opened, and the drainage of the upper Great Lakes escaped northeast from the Lake Huron basin across southern Ontario by way of the Ottawa Valley (Fig 289*C*) As the ice wasted away, there was gradual recovery from the depression it had caused, resulting in progressive upwarp of the region northeast of a hinge line that ran through central Michigan and southern Ontario (Fig 289) This ultimately raised the Ottawa outlet until the lowest spillway was across the edge of Niagara cuesta at Lewiston At this stage, the Niagara River increased greatly in size

Various other important lakes were formed by the glaciation The Finger Lakes of central New York, for example, mark open valleys carved in the margin of the Allegheny Plateau by northward-flowing streams in preglacial times As the ice rode southward, it gouged deeply where it was crowded into these narrow valleys Upon the retreat of the ice, these overdeepened places became lakes The greatest of all the glacial lakes was *Lake Agassiz,* previously mentioned (Fig 286), which formed in the plains of eastern North Dakota, northwestern Minnesota, and Manitoba, while the ice still occupied the basin of Hudson Bay, impounding the water until it overflowed the divide to the south by way of the Minnesota River Although the lake attained an area nearly five times as great as that of Lake Superior, it was relatively shallow, the old strandlines indicating a probable maximum depth of about 400 feet at the international boundary. The disappearance of the ice allowed the lake to drain away into Hudson Bay. The floor of the former Lake Agassiz is now the remarkably flat and fertile wheat land of North Dakota and the Red River Valley of Manitoba (Fig 280)

## End of the Ice Ages

If our time scale for the Pleistocene epoch in any sense approaches reality, it is clear that we probably are now in a minor interglacial

subage in which the icefields have shrunk from a maximum of 32 per cent of the area of the land surface of the Earth to about 10 per cent There are still more than 5,000,000 square miles of ice sheets in the Antarctic Continent and Greenland, and the polar seas are choked with floe ice, while lofty mountains the world around bear active glaciers Furthermore, it is estimated that a decline in the mean annual temperature of not more than 5° C would bring a return of the ice sheets as they were during the last advance[1]

Judged by every criterion we know, the interglacial ages vastly exceeded the time that has elapsed since the last ice sheets began to wane, and fossils preserved between the drift sheets prove beyond doubt that the climate at times during those interglacial ages was appreciably warmer than it is now Furthermore, there is clear evidence that postglacial world climates reached a maximum of warmth between 6000 and 4000 years ago and since then, with minor oscillation, have become cooler and more moist down to the present time Whether the ice sheets will spread again or will disappear completely during the next few thousands of years, it is quite impossible to judge, but clearly the *Present* is only an age in the Pleistocene epoch

Meanwhile the sword of Damocles hangs over us If the ice sheets should again spread to the limits they occupied a few thousands of years ago, mass migrations would occur on a scale without precedent in the history of mankind, for the densely populated centers of Europe and the United States, to say nothing of all Canada, would slowly become uninhabitable And if, on the contrary, the climate should return to its geologic norm and the last of the ice sheets should disappear, the meltwater would raise sealevel by 70 to 100 feet, slowly submerging all the great seaport cities of the world In any event, the changes will come too slowly to concern anyone now living, but they may profoundly shape the destiny of civilization within the next few thousands of years

We can only guess when the end of the Ice Ages will come, as we contemplate some of the problems it will entail for mankind!

## References


[1] *Glacial Geology and the Pleistocene Epoch*, by Richard Foster Flint 589 pages John Wiley and Sons, New York, 1947

This comprehensive and entertainingly written volume was an invaluable source in the preparation of this chapter

[2] *Time Relations in Ocean Sediments*, by C S Piggot and W D Urry Bulletin of the Geological Society of America, Vol 53, 1942, pp 1187–1210

## Collateral Reading

*The Changing World of the Ice Age*, by R A Daly 271 pages Yale University Press, New Haven, 1934

*The Quaternary Ice Age*, by W B Wright 478 pages 2d ed The Macmillan Co, London, 1937

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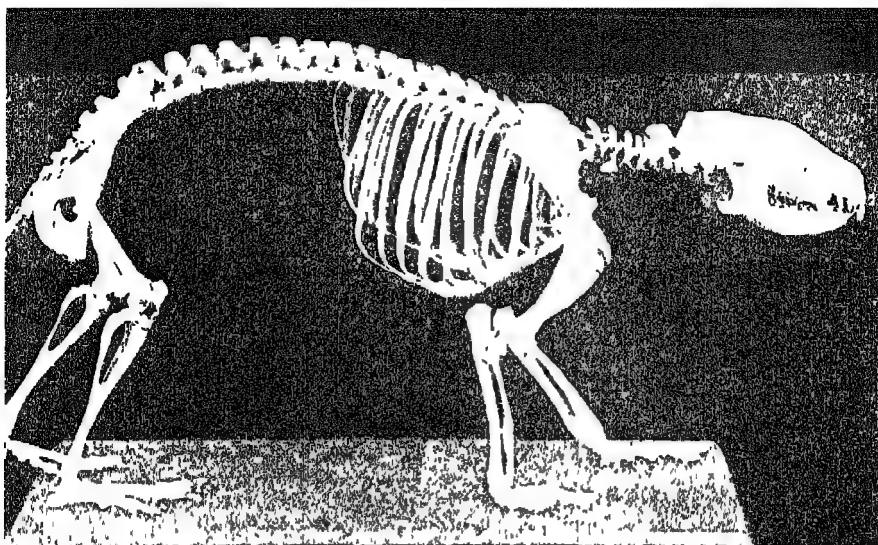


*Fig 290 Skeleton of the modern hedgehog, a persistently primitive and generalized mammal About 2/5 natural size*

Chapter 19

# MAMMALS INHERIT THE EARTH

With the extinction of the dinosaurs at the end of the Mesozoic, the way was open for the mammals to begin their conquest of the world Although small and unimpressive at first, they evolved rapidly and soon eclipsed all other forms of animal life, so that the Cenozoic has well been called *The Age of Mammals*

## Trends of Mammalian Evolution

Comparative study of early Cenozoic fossils clearly indicates that the first mammals resembled the modern hedgehog (Fig 290) in the following respects (1) they were small, (2) they were short-legged and walked on the soles of the feet, (3) they had five toes on each foot, (4) they had forty-four teeth of which all but the canines were short-crowned, (5) their brains were small and their intelligence was of a low order, (6) they were long-faced, the jaws exceeding the brain-

crease in size Unlike the hedgehog, however, they had a long tail From ancestors of this sort all the modern orders of mammals evolved In this development four major trends can be detected in most of the groups

First, there was a marked *increase in size* The first mammals were small, and every group of large mammals can be traced back to small ancestors in the early Cenozoic rocks The Eocene ancestor of the horse, for example, was not larger than a fox, that of the camel not bigger than a jack rabbit, and that of the elephant not greater than a large hog The Eocene forebears of man, likewise, were the size of squirrels!

FIG 291 Brains of archaic mammals (left) and of modern mammals (right) paired so that brains of animals having equal body size are side by side Adapted from H F Osborn

A second advance was in *brain power* This involved not merely a larger brain but an increase in ratio of brain to body weight The latter is graphically shown in Fig 291, in which the brain of an ancient mammal (on the left) is paired against that of a modern mammal of the same size The striking fact is that the greater size of the modern brain is in each case due to increase in the cerebrum, which is the seat of memory and reason However, advance in brain power has been unequal in the several orders At one extreme stand the insectivores (for example, shrews, hedgehogs, and moles) which have improved but little and have survived as stupid, retiring creatures, and at the other extreme stand the highest primates, with skulls distended by gray matter, capable of pondering the mysteries of time and space, and of harnessing atomic energy!

A third specialization concerned the *teeth* In the primitive placental mammal the cheek teeth had sharp piercing or shearing cusps

but the crown was low, and the tooth quickly attained its full growth Some, like the insectivores, chose a diet of insects and other such delicate morsels, and these have retained primitive teeth Others with an omnivorous diet, like the swine, the bear, and man, have developed low blunt cusps Carnivores, on the contrary, have narrow shearing cheek teeth for cutting, and greatly enlarged canines for holding and

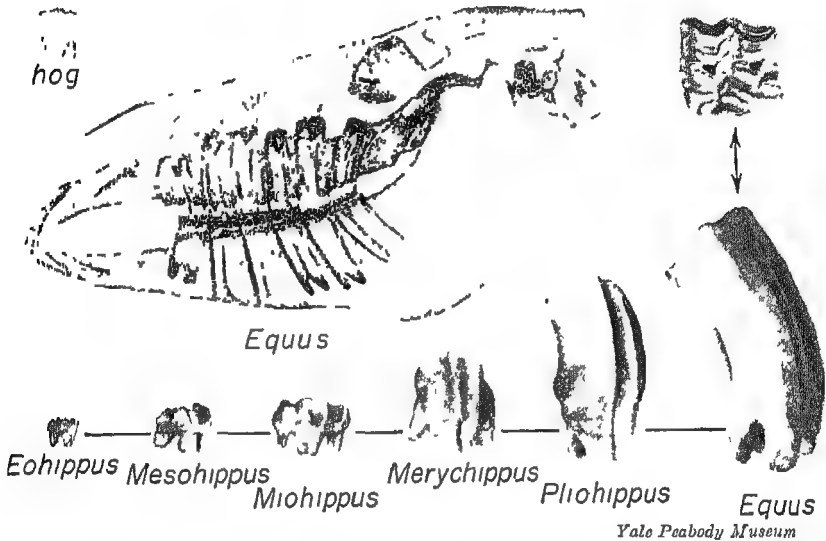



Fig 292 Low-crowned and high-crowned cheek teeth Top left, molar tooth of a hog in which the crown is shorter than the roots, right, corresponding tooth of a modern horse, *Equus*, in which the crown is about 5 times as long as the roots Center, skull of the horse (×1/6) dissected to show the high-crowned cheek teeth in place Lower row, corresponding upper left molars of fossil horses from *Eohippus* to *Equus*, all at a uniform scale (about ½ natural size) The crown is low in *Eohippus*, *Mesohippus*, and *Miohippus*, then increases rapidly in height from *Merychippus* to *Equus* The crown view of the worn tooth shows the ridges formed of the enfolded enamel The skull was dissected by S H Chubb

tearing flesh The most remarkable specialization is seen, however, in the grazing animals of the prairies, whose teeth must resist the wear of the harsh and commonly dusty grasses and must maintain a rough grinding surface In these the cheek teeth become large and high-crowned and continue to grow throughout life (Fig 292) Furthermore, the enamel is deeply enfolded into the crown, so that even after wear it forms sharp ridges, thus maintaining a good grinding surface Each order has a distinctive pattern of enfolded enamel, making it almost as easy to identify the order of a fossil mammal by a single jaw tooth as by a whole skeleton (Fig. 293).

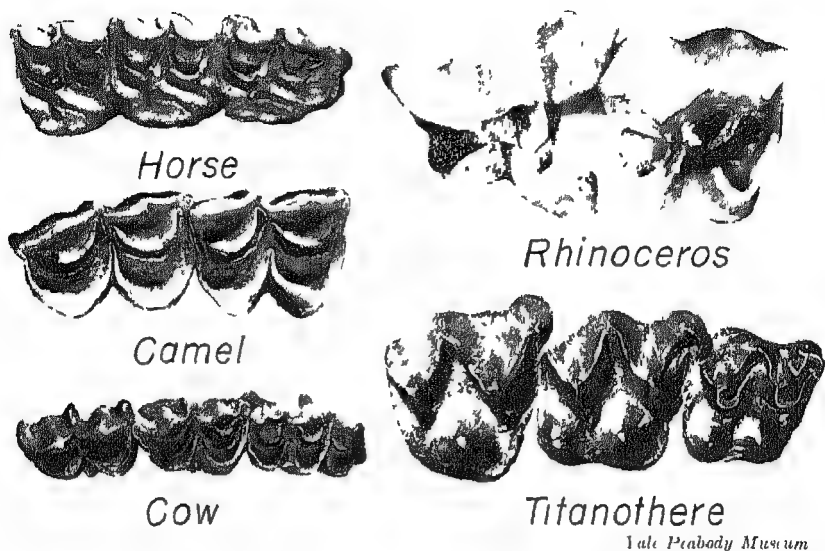



FIG 293 Crown view of left upper molar teeth of horse, camel, cow, rhinoceros, and titanothere, to show the distinctive patterns of the enamel folds (All on the same scale, about ×½)

A fourth trend of evolution lay in *specialization of the feet* Primitively the feet were short, and the animal walked flat on the soles with the heels touching the ground (Fig 290), but during the ages marked specialization occurred according to environment and habits Tree-dwelling types, like the monkeys and squirrels, developed prehensile hands with opposable thumb and great toe, carnivores evolved claws to seize and hold struggling prey, and the herbivorous animals of the plains, dependent for safety on fleetness of foot, underwent a remarkable specialization involving a rise onto the very ends of their toes, the development of hoofs, and a reduction and loss of some or all of the side toes.

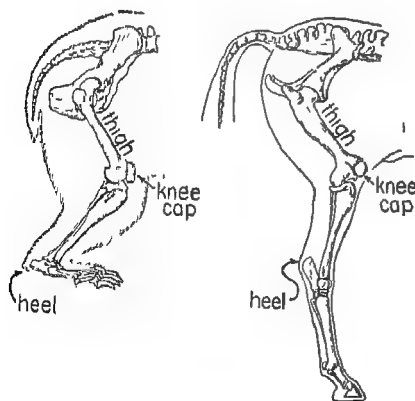



FIG 294 Hind limbs of bear (left) and horse, showing correspondence of parts

In swift running, an animal tends to rise up on its toes to attain a longer stride, and those that are endowed with long slender limbs have a natural advantage. In the struggle for existence, therefore, many of the plains animals were subjected to an age-long selection in which a great premium was placed on longer limbs and the ability to remain on the toes. The ultimate result is illustrated by the limb of a modern horse, contrasted with the unspecialized limb of a bear (Fig. 294). Above the heel there is little difference in size and proportions, the greater height of the horse being due to the elongation of the foot and to the fact that he stands on the very end of the toe with the heel far above the ground. This affords a great stride and leaves the powerful leg muscles bunched near the body where they can swing the slender extremity of the limb without sharing in its motion. The hoof developed, of course, as a protective armor for the tip of the toe.

Fig. 295. Loss of lateral digits in the horse. From right to left, the lower fore limbs of *Eohippus* of the Eocene epoch, *Mesohippus* of the Oligocene, *Merychippus* of the Miocene, and *Equus*, the modern horse. Corresponding digits bear the same numbers throughout.

Since the middle toes of a mammal are primitively and normally longer than the side toes, a rise to the ends of the digits lifts the side toes off the ground and leaves them dangling. In this condition they tend to degenerate and disappear (Fig. 295). In the odd-toed, hoofed mammals (Order Perissodactyla), the axis of the foot lies in the middle digit and, in the reduction, digits 1 and 5, as a rule, disappeared, leaving a three-toed foot. Heavy-bodied types such as the rhinoceros did not proceed further in this direction, but in the horse, digits 2 and 4 were reduced to mere vestiges (Fig. 38, p. 64, and Fig. 295), leaving a one-toed foot. In the cloven-hoofed mammals (Order Artiodactyla), the axis of the foot lies between digits 3 and 4. In this group, digit 1 was lost at a very early stage, producing a four-toed foot, such as is retained in the hog. Further specialization led to the

*Fig 296 Restoration of Phenacodus, a condylarth from the Paleocene of Wyoming The grasslike vegetation consists of sedges, not true grasses From a painting by Charles R. Knight.*

simultaneous reduction and loss of digits 2 and 5, and the production of a two-toed foot, such as that of the cattle, the deer, and the camel

## THE PALEOCENE VANGUARD

At the beginning of Cenozoic time, the mammals expanded like a race delivered from bondage Although only three orders are recorded from Cretaceous rocks, fourteen are now known from the Paleocene series[1] Notable among these are the *multituberculates, marsupials,* and *insectivores* that survived from the Cretaceous, and the *primates, rodents, carnivores, condylarths,* and *amblypods* that first appeared with the Paleocene Nearly all these early mammals were small, few of them exceeding a large hog in size

The *multituberculates* (Fig 298) were small gnawing plant feeders superficially resembling a ground hog, but their cheek teeth were large

AMERICAN MUSEUM OF NATURAL HISTORY.

*Fig 297 Restoration of Coryphodon, an amblypod from the lower Eocene of Wyoming From a painting by Charles R Knight*

and bore numerous cusps or tubercles, whence the name Multituberculata

The *marsupials* were essentially like the modern opossum and at this time were possibly world wide in distribution Outside of Australia and South America, however, they have never competed successfully with more progressive types and have never risen above the modest and retiring role played by the living opossum

*Insectivores* were likewise small and much like the modern shrew and hedgehog They appear to be the ancestral stock from which the other groups of placentals evolved, but the insectivores themselves did not share in that evolutionary advance

*Rodents* include the modern gnawers, such as mice and rats and squirrels The oldest representative of this order was found in the Paleocene beds of Montana in 1937

*Primates* are represented in the Paleocene by small half-apes (tarsioids and lemurs) scarcely larger than squirrels.

*Creodonts* were precursors of the modern carnivores. Even in Paleocene time they showed considerable specialization, some being doglike and others catlike. Some had shearing teeth and sharp claws, others strangely blunt teeth and flattened toenails. Their brains, however, were less than half as big as those of modern carnivores of equal stature, and they must have been stupid brutes (Fig. 308).

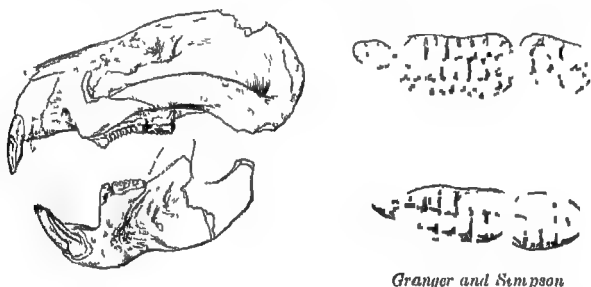
The *condylarths* and *amblypods* (primitive ungulates) were the dominant orders of herbivorous animals during Paleocene time. The

*Granger and Simpson*

Fig. 298. A Paleocene multituberculate, *Taeniolabis*, from New Mexico. Side view of skull (×¼) and crown view of upper and lower left cheek teeth (enlarged).

condylarths were lightbodied and relatively agile, the amblypods stocky and ponderous. *Phenacodus* (Fig. 296) was a typical condylarth. The slender body, arched back, long tail, and short, five-toed feet give it a superficial resemblance to the carnivores, but each toe bore a small hoof, and its teeth were clearly those of a plant feeder. The brain was relatively small, and the teeth primitive and low-crowned. The condylarths appeared early in the Paleocene and ranged upward to the middle of the Eocene epoch, when they were replaced by the more advanced ungulates.

*Coryphodon* (Fig. 297), a typical Paleocene amblypod, was about waist-high to a man. It was thickset and had stout legs and blunt, five-toed feet, each toe bearing a hooflike nail. The canine teeth were tusklike, but the cheek teeth were relatively small and low-crowned. The amblypods appeared early in the Paleocene and ranged through to the close of the Eocene epoch. The earliest forms were scarcely larger than a sheep, but they increased rapidly in size and culminated in *Uintatherium*, which had the bulk of a circus elephant and was the largest of the American land animals during late Eocene time.

YALE PEABODY MUSEUM

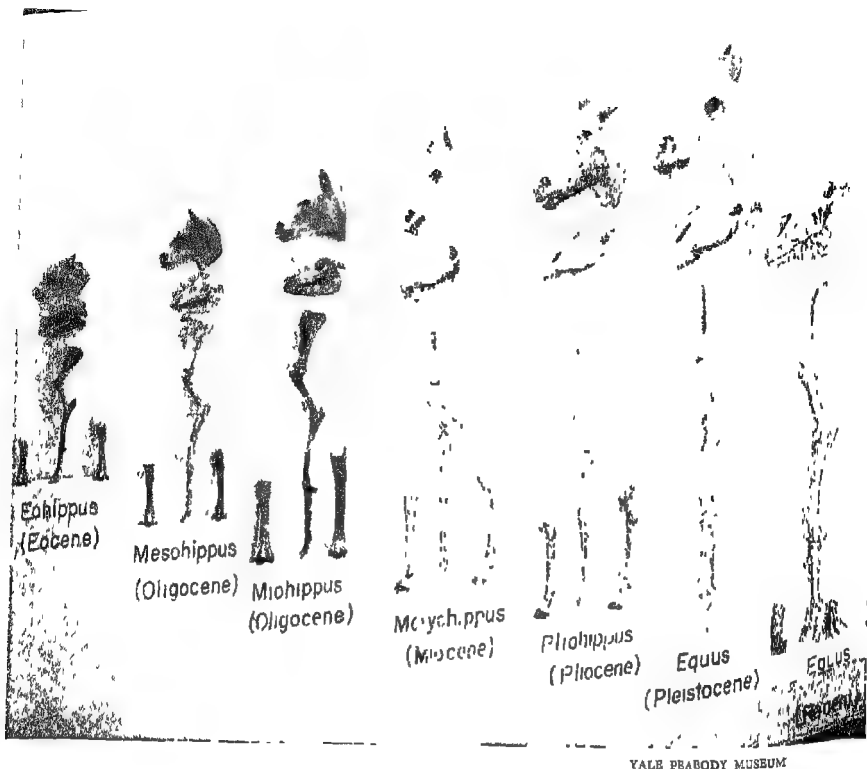



*Fig 299 Evolution of the horse, as shown by limbs and skulls from successive zones in the Cenozoic rocks of western United States The fore limb in each case indicates the approximate height at the shoulder, and the position of the skull shows the height at which the head of each genus of horse was carried*

In short, the Paleocene faunas would have presented a strange, unfamiliar appearance to a modern, for the dominant forms belonged to groups that are long since extinct, and many of the groups that are now dominant were completely lacking

## Eocene Immigrants

At the beginning of Eocene time the ancestors of the modern horse, the rhinoceros, the camel, and other modern groups of mammals appeared simultaneously in Europe and the United States This sudden advent implies that these modernized stocks had been evolving somewhere in the northern land mass and at this time migrated southward along two different routes From this stage on, the history of several

of these stocks can be followed in detail and constitutes one of the most fascinating chapters in the history of life

## Cenozoic Parade

**Eohippus and His Progeny.** The horse was a native of North America from early Eocene to late Pleistocene time and underwent most of its development here Skeletons assembled from successive horizons reveal a gradual evolution in teeth, limbs, feet, and size hardly equaled for any other stock of animals The record is graphically shown in Fig 299

*American Museum of Natural History*

Fig 300 *Eohippus*, the "dawn horse," from the Eocene (Wind River) beds This horse was about a foot high at the shoulder Restoration by Charles R Knight

*Eohippus*, the "dawn horse," oldest known member of the race, was a graceful little animal, scarcely a foot high, with a slender face, arched back, and long tail (Fig 300) Its hind feet bore three toes, and the front feet four toes Its Paleocene ancestor, we may infer, possessed five toes all around, but no such stage has yet been discovered

The evolution that followed was long and complex but may be epitomized by noting three of the stages intermediate between *Eohippus* and the modern horse, *Equus*

Of these, *Mesohippus* of the Oligocene, about the size of a sheep (Fig 299), had three toes on each foot, subequal in size and all touching the ground, so as to share equally in the animal's weight Its cheek teeth were still low-crowned, as were those of *Eohippus* (Fig 292)

*Merychippus* of the Miocene grew to the size of a small pony (Fig 299) It possessed three toes on each foot, but the middle toe was much the largest, the others failing to touch the ground and dangling like the "dew-claws" of cattle The jaws of this little horse had

* According to Simpson (1945, p 136), the name *Hyracotherium* has legal priority over *Eohippus*, having been applied to the same genus in Europe 36 years before the name *Eohippus* was coined For the present we continue to use the latter name because it is so much more widely known and applied

lengthened and deepened appreciably, for its molar teeth were becoming high-crowned and prismatic (Fig 292)

*Pliohippus* of the Pliocene, the first one-toed horse (Fig 299), was somewhat larger than *Merychippus,* and had high-crowned teeth (Fig 292) and long jaws approximating the condition seen in a modern horse. The side toes were represented only by a pair of splint

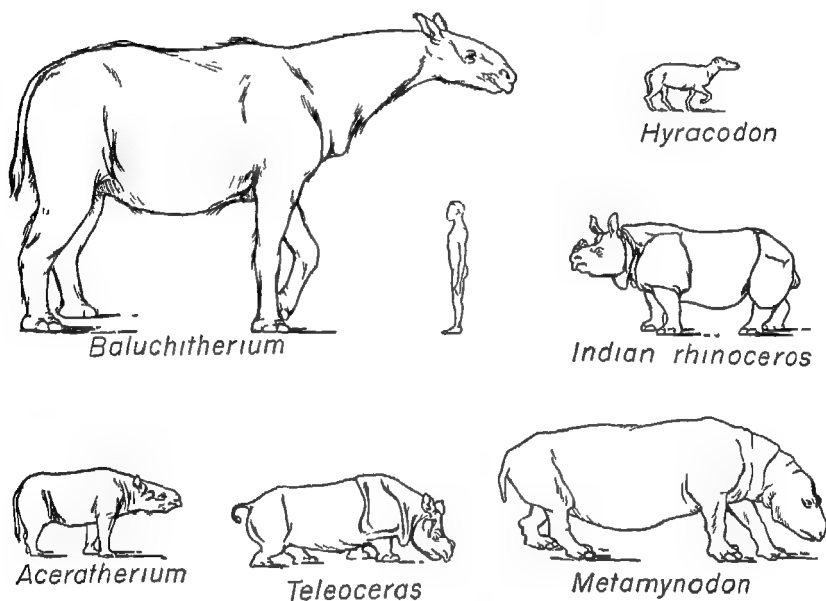



FIG 301 Fossil rhinoceroses (facing right) and the modern rhinoceros (facing left) The human figure gives the scale *Hyracodon* is one of the running rhinos of Oligocene date, *Metamynodon* is one of the amphibious rhinos, also of Oligocene date, *Baluchitherium,* the greatest land mammal of all time, represents the giant tribe of baluchithere rhinos, the others represent the main line of rhinoceroses

bones lying alongside of the cannon bone (Fig 38, p 64) and invisible externally The modern horse, *Equus,* appeared about the close of the Pliocene epoch and survived in America until after the last of the Pleistocene ice ages These wild horses roamed the American plains in great herds until late in the epoch and then, for some unknown reason (possibly an epidemic like the modern hoof-and-mouth disease or sleeping sickness), became extinct Meanwhile, fortunately, they had spread to the Old World (probably via Alaska and Siberia), where they survived to become a servant and friend of man The present wild horses are descendants of those brought over by the Spaniards during their early conquests

**Rhinoceroses.** The rhinoceros (Fig. 301) also is primarily of North American stock. The group first appeared near the beginning of the Eocene and by early Oligocene time was abundant and had specialized into three distinct tribes: (1) the *true rhinoceroses,* which gradually developed into modern types, (2) the *running rhinoceroses,* which were small, light-bodied, and fleet-footed; and (3) the *amphibious rhinoceroses,* which were semiaquatic and, like the hippopotamus, became thick-bodied and very short-legged. The last two stocks died

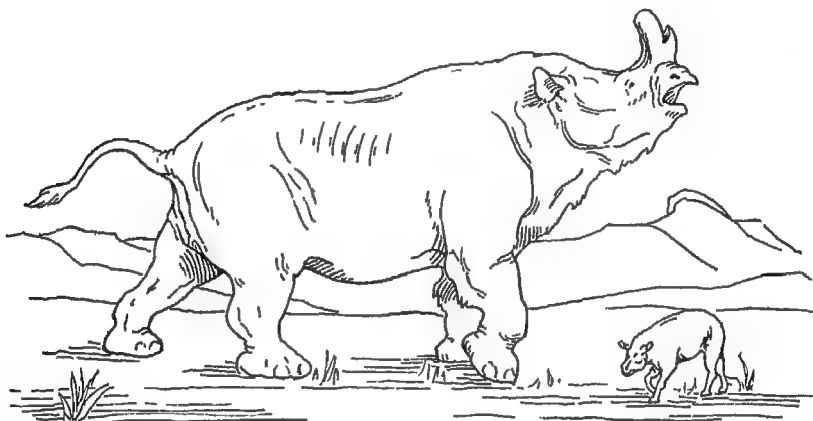



Fig. 302. First and last of the titanotheres. Right, *Eotitanops* of the Eocene epoch, left, *Brontotherium* of the Oligocene epoch. The latter stood about 8 feet high at the shoulders. Adapted from a figure by H. F. Osborn.

out during Oligocene time, but true rhinoceroses were very common in the Great Plains region during Miocene time and were then more varied than they are today in East Africa. One of the striking Miocene forms was *Teleoceras,* a barrel-chested rhinoceros with extremely short legs (Fig. 317). In America the rhinoceroses declined to extinction in the Pliocene epoch, but those which had migrated into the Old World survived.

The early rhinoceroses were small and hornless. The true rhinoceroses were still scarcely 3 feet high in Oligocene time, although one of the amphibious tribe then reached a height of 6 feet and a length of 14 feet. In America few of the Cenozoic forms were as large as modern species, but in Asia an aberrant stock of hornless giants developed during Oligocene and early Miocene time and in *Baluchitherium* (Fig. 301) attained the largest size of any known land mammal of any age. This great beast stood about 18 feet high at the shoulders and was at least 25 feet long.

**Titanotheres.** Another magnificent tribe of mammals, remotely related to the rhinoceroses and the horses, was the *titanotheres* (Fig. 302). These were ponderous beasts of rhinoceros-like appearance, many of them with great nasal horns made of bony outgrowths from the skull. Early Eocene titanotheres were scarcely larger than a big hog and were hornless, but the tribe developed rapidly to great size before its extinction about the middle of the Oligocene epoch. One of the latest was *Brontotherium*, which stood about 8 feet high at the shoulder and far outbulked the largest living rhinoceros. During Oligocene time this was the largest land animal in America.

Titanotheres are known only from the United States, Mongolia, and Europe. They left no descendants, either collateral or direct. Like the rhinoceros, they possessed three toes on each hind foot and four toes on each front foot. The great weight probably prevented further reduction of the digits in either of these stocks of plains-dwelling mammals.

**Chalicotheres.** Perhaps the strangest of all the odd-toed mammals were the *chalicotheres*, a group now extinct, but represented by *Moropus* (Fig. 316) in the Great Plains region during Miocene time. The skull of this grotesque creature was shaped like that of a horse, but its body was deep and short-coupled like that of a camel, and its feet bore narrowly compressed claws. There were three toes on the hind feet and three, plus a vestige of the fourth, on the front feet. This is the best-known American form, and its remains are not rare in the Miocene beds of Nebraska, but the chalicotheres were present also in Europe and Asia and are known to have lived from late Eocene to late Pliocene time.

**Camels.** Camels underwent a long evolution remarkably paralleling that of the horse. One of the earliest genera, *Protylopus* of the upper Eocene, was a slender, four-toed creature scarcely larger than a jack rabbit. By Oligocene time there were camels about the size of sheep associated with *Mesohippus* of the same size. These little camels displayed their true affinities in the enamel pattern of their teeth and in the peculiar carriage of their heads. The toes had by this time been reduced to two on each foot, but these were still free.

In Miocene time the camels diverged into several tribes. The main line continued through *Procamelus* of the Miocene into *Camelops* of the Pliocene and Pleistocene. The latter survived until comparatively recent time in southwestern United States. A larger genus (*Gigantocamelus*) inhabited the Great Plains during Pleistocene time and

reached a height of 7½ feet at the shoulders, carrying its head about 9 feet above the ground

Among the divergent stocks that appeared in the Miocene were the small and very slender "gazelle camels" and the long-necked "giraffe camels"

Like the horses, the camels lived through the several ice ages in America and then for some unknown reason died out before the arrival of the white man

*Yale Peabody Museum*

Fig 303 An oreodon, *Merycoidodon gracilis* Model by Richard S Lull, based on a skeleton from the Oligocene (White River) beds of Sioux County, Nebraska The animal was about as tall as a sheep.

**Oreodons.** One of the most abundant Mid-Cenozoic animals of western United States was the oreodon (Fig 303) These small creatures are not closely allied to any living animals and are therefore difficult to characterize in nontechnical terms Most of them were of the size of sheep or goats Although they appeared long-bodied and short-legged like a hog, this resemblance was quite superficial In a sense they were remote cousins of the camels, for they had similar teeth, they were even-toed, and they were cud-chewers They were both browsers and grazers, and, if we may judge by the extraordinary abundance of their remains in the Big Badlands of Dakota, they roamed the plains in vast herds They appeared in late Eocene time, reached a climax in the Oligocene, and persisted into the early Pliocene before dying out, but during all this time they were strangely conservative, retaining four toes (some a small fifth) and short legs, keeping their low-crowned teeth, and failing to increase notably in

size Their short-leggedness was a mark of conservatism, their toes had failed to lengthen as rapidly as those of most other plains animals So far as is known, oreodons were confined to North America

**Entelodonts.** The entelodonts, or "giant pigs," were another group of even-toed mammals that assumed a spectacular role for a short time during the Mid-Cenozoic (Figs 304, 316) They were remote cousins of the swine and, like the latter, were adapted for rooting and grubbing in the forest They are characterized by a large bony extension from the zygomatic arch of the cheek, a structure whose function is entirely problematic They appeared during Oligocene time, reached their greatest size (6 feet high at the shoulder) in the early Miocene, and then died out

FIG 304 Restoration of an entelodont or "giant pig," *Archæotherium*, from the Oligocene beds of the Great Plains After W B Scott The largest of the entelodonts stood 6 feet high at the shoulders

**Bovids.** Cattle, sheep, and goats belong to the family Bovidæ, which also includes the bison, the musk-ox, and the antelopes In spite of superficial differences, these animals are closely related and have many peculiarities in common Among other things, they all lack front teeth in the upper jaw, and they possess true horns with an unbranched bony core covered by a horny sheath Since the beginning of civilization this great family has contributed more than any other to human welfare To hunting peoples it has been a source of food and of clothing and tents and thongs as well Indeed, the very beginning of civilization is closely linked with the domestication of cattle, goats, and sheep, and the tending of flocks

Unlike the horses and camels and rhinos, this family is essentially an Old World stock The oldest known forms appeared in Eurasia late in Miocene time, having evolved from stocks now extinct They became highly diversified there in the Pliocene and reached their modern estate during the Pleistocene epoch, the cattle apparently having developed out of certain antelopes During the Ice Age most of them migrated out of Europe, finding a more suitable environment in the plains of Asia and Africa, but only a few managed to reach America The buffalo is one of the exceptions It probably arrived via the Bering land bridge about the beginning of Pleistocene time, soon became enormously abundant, and developed into numerous

species, some of which were much larger than the living forms The musk-ox also reached North America in Pleistocene time, having no difficulty in crossing the snowfields of the North

**Elephants and Their Kin** The Indian and African elephants are the sole survivors of a spectacular race that is now verging on

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Fig 305 Reconstruction of proboscidian heads, showing stages in the development of tusks and trunk 1, *Moeritherium* (early Oligocene), 2, *Phiomia* (Oligocene), 3, *Elephas* (Recent) *T,T*, incisor teeth, *L*, upper lip, *N*, nostrils After a drawing by Charles R Knight

extinction During Pliocene and most of Pleistocene time elephants of many sorts ranged over Europe, Asia, Africa, and North America, and, while the last glacial ice was waning, they were still more common in eastern United States than they are now in East Africa

Compared with the ancestral placental mammal (Fig 290), the elephants show amazing specialization in several respects Not the least of these is the fusion of nose and upper lip to form the trunk or *proboscis*, from which this order takes the name *Proboscidia*

The earliest known proboscidians are found in North Africa, which appears to have been their ancestral home Several species of the

genus *Mœritherium* (Fig 305, 1) have been discovered in the late Eocene and early Oligocene beds of the Fayûm Desert not far west of Cairo When these beds were forming, the climate was humid in North Africa, and the Fayûm area was occupied by the delta of an ancient Nile The mœritheres were thickset animals scarcely waist-high to a man, and apparently they were semiaquatic, living in and along the river They had neither tusks nor trunk and showed little resemblance to an elephant, yet they displayed the beginnings of specializations that betray their relationship As shown in Fig 305,

Fig 306 Cheek tooth of mastodon (left) and elephant (right)

1, the head was long and low, and the upper lip was prehensile, as in a modern tapir Among the front teeth the second incisors were enlarged and bore a band of enamel on the outer side These are the teeth that developed into tusks in the later proboscidians The limbs were thick and stout but not otherwise specialized

In this same region a more advanced type, *Phiomia*, appeared early in the Oligocene epoch, and for a time it lived along with the last of the mœritheres This animal (Fig 305, 2) had the proportions of a small elephant and was about shoulder-high to a man Its jaws were long and its head was low, as compared with an elephant The second pair of incisors was much enlarged and was directed strongly forward as small tusks, in both the upper and lower jaws A real trunk was present, though still relatively short The cheek teeth of *Phiomia* were rather large but low-crowned and bore three pairs of low, blunt cones

Out of this early stock evolved an amazing variety of animals known as *mastodons* In most regards they resembled the elephants, but their teeth were quite different (Fig 306) The name mastodon

(Gr. *mastos,* breast, + *odous,* tooth) refers to the characteristic shape of their cheek teeth, in which the cusps were few in number and occurred as pairs of large blunt cones presenting a fancied resemblance to human breasts

*Phiomia* possessed three pairs of such rounded cusps on each molar tooth Many of its descendants retained this number, but others added one or more pairs of cusps, and in all the later mastodons there was a tendency to unite individuals of each pair by a cross ridge (Fig 306) The mastodons possessed their normal complement of permanent cheek teeth (six in each side of each jaw) throughout adult life

Most of the mastodons had tusks in the lower as well as the upper jaw In many, the lower tusks remained smaller than the upper, but in some stocks they were large and greatly specialized A striking example is presented by the long-faced *four-tuskers* shown in Fig 317 In the *shovel-tuskers,* on the other hand, the lower tusks were flattened and broadened to form a scooplike organ, and in the *dinotheres* they were strongly recurved

Mastodons migrated widely over Eurasia during Miocene time and reached North America near the middle of the epoch via a Siberian-Alaskan land bridge Among these immigrants were long-faced *four-tuskers* and *shovel-tuskers,* both of which were common in western United States during late Miocene and part of Pliocene time but died out during the latter epoch More conservative mastodons survived until after the last glaciation, and the fine Pleistocene species, *Mammut americanus* (Fig 319), may have been exterminated by primitive man within the last several thousand years

The mastodons were predominantly browsers, living in the timber, and their cheek teeth were relatively unspecialized

The *elephants,* on the contrary, were grazers and were for the most part at home on the plains They are readily distinguished from the mastodons by a remarkable specialization of the cheek teeth, in which the cross ridges have become numerous and high and thin As a result, the tooth is enormous in size, is high-crowned, and is made up of many transverse plates of enfolded enamel embedded in cement (Fig 306) So large have these teeth become that there is room for only one in each side of each jaw—even in an elephant's mouth! Hence, the full set of teeth does not appear simultaneously, as in the mastodons and other mammals Instead, one tooth appears in each side of each jaw, and as it is worn out, a second tooth grows down,

crowding out the first and taking its place In this manner the six teeth that should exist in each half of each jaw succeed one another during the life of the individual, which normally has only four grinding teeth in the mouth at one time In turn, the jaws have become very short, so that the head of the elephant appears short and high as compared with that of a mastodon (*cf* Figs 318, 319).

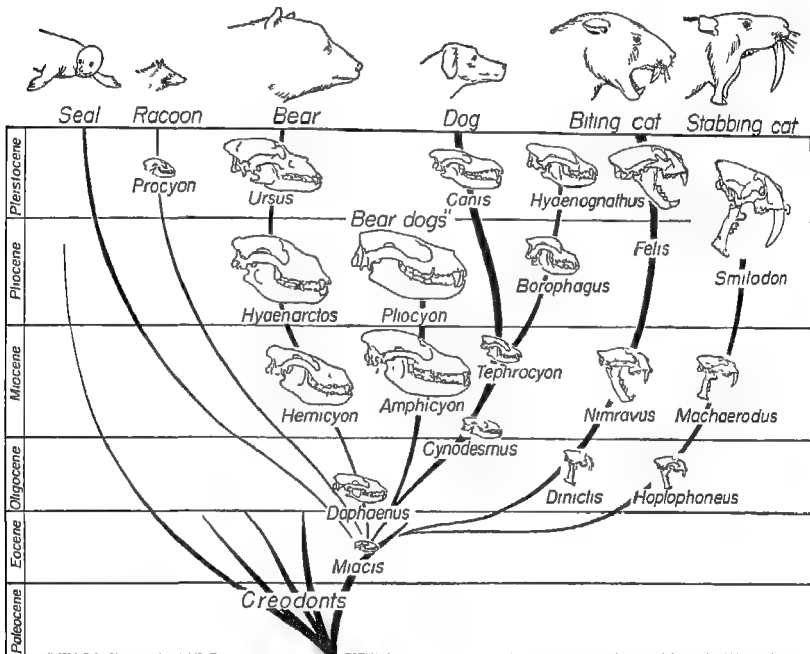



FIG 307 Family tree of the carnivores, all on the same scale Note that the "bear dogs," a branch of the canine tribe, attained large size during the Miocene and Pliocene epochs and then became extinct Diagram based on data from Matthew and Romer

Of this family (Elephantidæ) the genus *Mammuthus* reached North America during the Pleistocene and was then represented by a number of species The best known of these is the *woolly mammoth* that lived on the tundra and in the forest bordering the ice fields, and ranged across both Eurasia and northern North America In Siberia frozen carcasses have been found, showing that it bore a heavy coat of woolly hair (Figs 13, 318) Other species inhabited the warmer regions, particularly the plains of the central and southwestern states One of these, the *imperial mammoth* of the Southwest, attained a height of 13 to 14 feet at the shoulders and bore

tusks as much as 13 feet long. In their present fossil state, a pair of such tusks weighs almost half a ton!

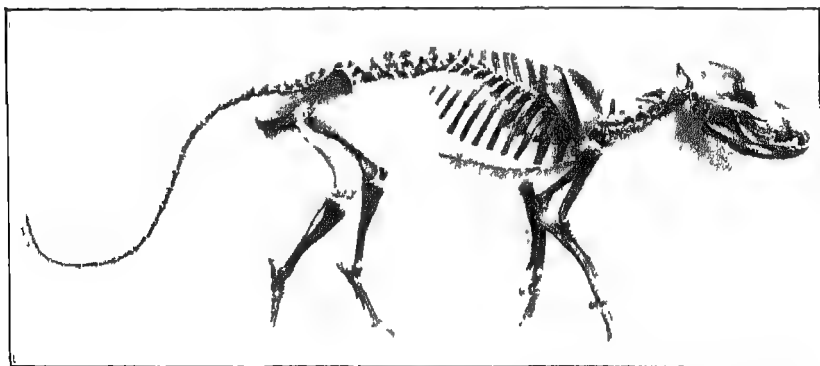
**Carnivores.** Flesh-feeders have a long and complex geologic history (Fig. 307). They are intelligent, travel easily, and are highly adaptive. The dog and cat show their typical specializations—clawed feet, enlarged canines, and narrow shearing cheek teeth. These are devices for holding and devouring active prey. Among the modern forms, the dogs, cats, bears, hyenas, raccoons, and seals represent as many well-defined families, but when they are traced back toward

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FIG. 308. Skeleton of a creodont, *Dromocyon vorax*, from the Eocene (Bridger) of Henry's Fork, Wyoming. Animal about the size of a large dog.

the early Cenozoic, these distinctions decrease, and they seem to converge toward a common Eocene ancestor.

Small primitive carnivores appeared in some abundance in the Paleocene, and during the Eocene epoch they diverged into at least five distinct families, adapted themselves to a wide variety of habits, and attained a considerable range of size, a few reaching the stature of a large bear. Some superficially resembled wolves (Fig. 308) or cats or other living types, but in all these early forms the brains were very small, as compared with those of modern carnivores, and they must have been a stupid lot. Moreover, certain specializations of teeth or other parts show that four of these families were incapable of developing into any of the modern carnivores. For this reason, they are commonly set off as a distinct order, the *Creodonta*.

Nearly all the creodonts were defective or inadaptive in some respects, and three of the families died out by the end of the Eocene, the other barely surviving through the Oligocene, with one genus

ranging up into the Pliocene in India. Thus the first great experiment in carnivore evolution came to an inglorious end!

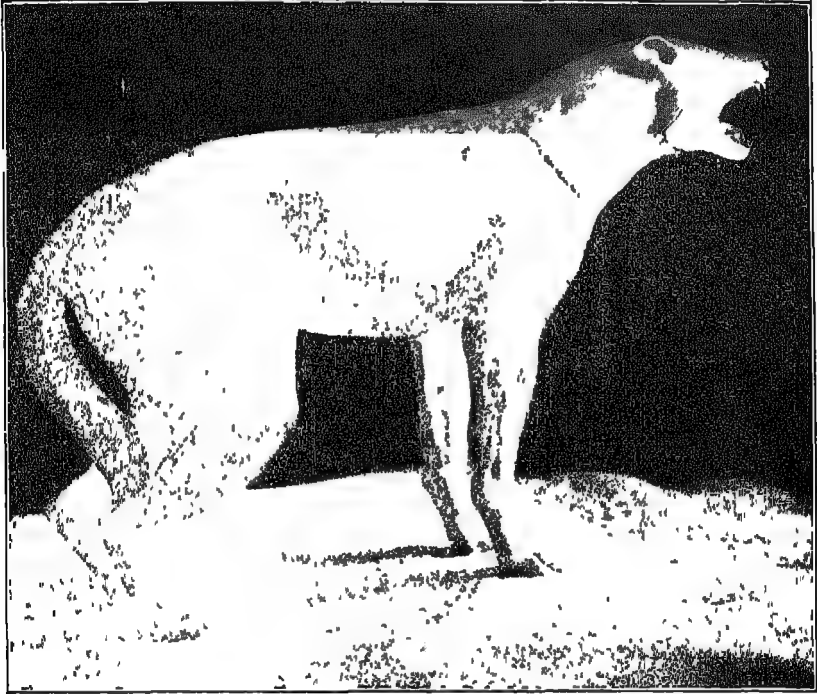
The fifth family of Paleocene and Eocene flesh-feeders had a higher destiny, even though, at the time, it would have seemed unpromising. It included small slender animals of the size of weasels, but

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FIG. 309. The dire wolf, *Canis dirus*, a common species in the asphalt pits at Rancho La Brea, near Los Angeles, California. Size about that of a modern timber wolf. Pleistocene. Modeled by R. S. Lull.

they had better brains than the rest, and adaptive feet, and their teeth were already specializing in the direction followed by the higher carnivores. Among these small Eocene types, the genus *Miacis* appears as a probable ancestor of all modern carnivores.

This second upsurgence of carnivores was under way in the Eocene, and before the close of that epoch the modern families began to emerge. The dogs were represented by *Pseudocynodictis*, of the size of a fox, and the cats by *Dinictis*, as large as a small leopard.

The Miocene was a time of rapid expansion, and before its close all the modern families were well defined In the Pliocene formations of western United States several species of wolves are represented, some large and others small, and by Pleistocene time the species were similar to modern ones In the asphalt deposits at Rancho La Brea in California a common fossil is the dire wolf (Fig 309), which had the stature of a large gray timber wolf

Fig 310 Skulls of biting cats (left) and stabbing cats (right) arranged in pairs of equivalent geologic date to show parallel development in these two tribes See also Fig 307 Adapted from W. D Matthew

By Miocene time the cats were diverging into two quite distinct families, the *biting* and the *stabbing* cats In the former, to which all modern cats belong, the lower and upper canines are subequal, and the lower jaw is strong Such cats kill their prey by biting In the stabbing cats the lower canines were small, and the upper ones were extended into saber-like blades, the lower jaw was weak and could be opened to a very wide angle so as to clear the upper teeth, which were then used to stab and tear, bleeding the prey to death (Fig 310)

The biting cats are well represented in both the Pliocene and Pleistocene deposits of America, culminating in the panther and the lynx *Felis atrox* of the Pleistocene faunas of southern California was of the size of a lion The true lion, *Felis leo*, ranged widely over Europe during the interglacial ages of the Pleistocene

The stabbing cats were even more common from Oligocene to late Pleistocene time, culminating in the *saber-toothed tiger* of the Rancho La Brea tar pits (Figs 24, 311) It was the last of its race, becoming extinct during the Pleistocene epoch

**Man's Family Tree.** Among all the animals, man's closest relatives are obviously the great apes and monkeys, but his family tree also includes two lower branches, the tarsioids and lemurs All these together constitute the order *Primates* (Fig 312)

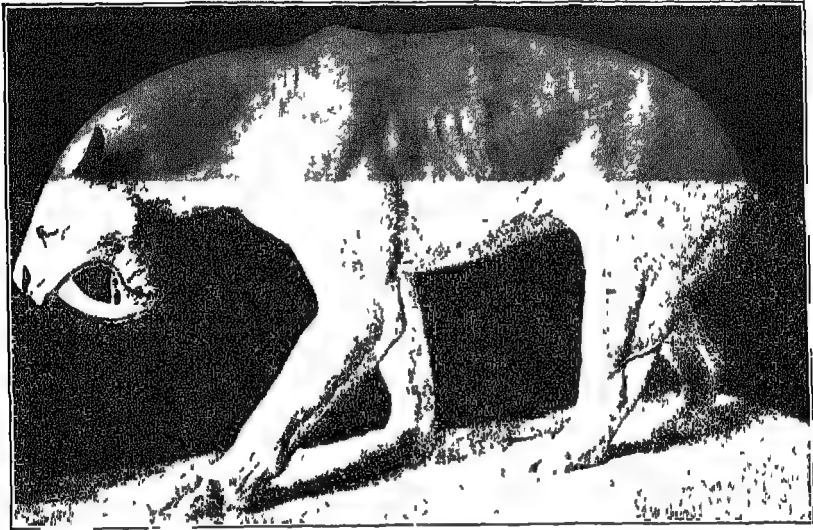
*Lemurs* (Fig 313) superficially resemble foxes rather than monkeys. They are distinctly quadrupedal, have long bushy tails, and

*Yale Peabody Museum*

Fig 311 The great saber-toothed tiger, *Smilodon*, common in the asphalt pits at Rancho La Brea, near Los Angeles, California Height about 3 feet Pleistocene Modeled by R S Lull

run on all fours Furthermore, their brains are relatively small, their muzzles slender and pointed, and their eyes far apart Their teeth, however, so closely resemble those of insectivores as to make it quite clear that the primates evolved out of primitive insectivore stock

The *tarsier* of the East Indies (Fig 314) is the sole survivor of a group of small primates that was far more common and more widely distributed during the early part of the Cenozoic era In nocturnal habits and some other respects the living form is highly specialized, but its ancestors among the fossil tarsioids bridge the gap between lemurs and monkeys. When compared with the lemurs, for example, tarsioids have a relatively larger brain and a shorter muzzle, but the most significant advance is in the eyes, which have migrated to the

front and are so close together that both can focus on the same point. This permits stereoscopic vision, an achievement which no other animals have attained save the monkeys and apes and man.

From the start, the primates specialized for an arboreal life, finding in the trees a refuge from their more powerful enemies on the ground. Prehensile hands and feet, with opposable thumb and great toe, were developed early, and the depth of focus inherent in stereoscopic vision opened new possibilities for locomotion in the trees. Instead of running along the limbs like a squirrel, such animals could safely hang by their arms and swing from limb to limb or even from tree to tree. Such free and rapid locomotion through the forest had great selective value. It led first to the evolution of the monkeys and shortly thereafter to gibbon-like apes, in which the arms are longer and more powerful than the legs. This in turn opened up new possibilities when the forests shrank, during late Cenozoic time, and some adventurous apes returned to life on the ground, for now their long arms gave them almost an upright position even when walking on all fours. Bipedal gait was thus easy to achieve and the hands were freed for better uses. Special interest therefore attaches to the tarsioids, whose vision in Paleocene time started us on the highway toward the human estate.

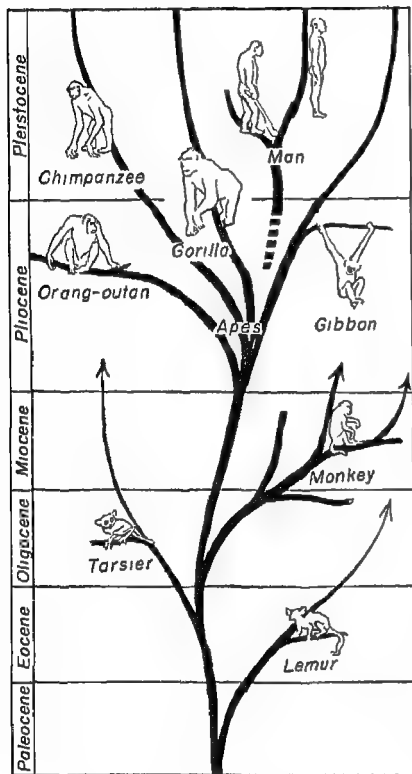



FIG. 312. Man's family tree.

The lemurs and tarsioids were well adapted to the mild, moist climate that prevailed over Europe and the United States during the early part of the Cenozoic era, and their fossil remains are relatively abundant, though fragmentary, in both these regions in Paleocene and Eocene strata. But during Oligocene time subtropical forests gave way to open plains in the present temperate lowlands, and the

primates retreated to lower latitudes. During the Miocene and Pliocene epochs the climate generally became both cooler and drier, and the tropical and subtropical forests gradually shrank to their present distribution. As a result, most of the higher primate evolution took place in parts of Africa and Eurasia that are not yet well known paleontologically.

Lemurs and tarsioids died out in the United States during Oligocene time, and no record whatever is known of monkeys or apes in all of North America. Small monkeys had reached South America (or had evolved there out of tarsioids) and survive to the present, undergoing an evolution entirely independent of the rest of the world, and reaching no greater attainment than that of the cebid monkeys used by itinerant organ-grinders.

*Yale Peabody Museum*

FIG. 313. Galago, the bush baby, a small lemur of rather advanced type from northern Rhodesia, Africa. The body of the animal is about 6 inches long.

The earliest evidence of Old World *monkeys* is a lower jaw with most of its teeth, found in Lower Oligocene beds of Egypt. The Miocene record is still very meager, and that of the Pliocene only somewhat better. Tropical forests provide a very poor environment for the preservation of fossils because the organic acids in the soil cause rapid decay of bones. For this reason we may never have as much evidence for the geologic history of the primates as for most of the other groups of animals. Pliocene monkeys are referred to families still living.

The manlike *apes* (Fig. 315) include four living types—the gibbon, the orang-outan, the chimpanzee, and the gorilla—and a number of fossil genera. In these the arms are longer than the hind legs, so that when walking on all fours the body is in an almost upright position, and bipedal gait is not difficult.

Although the living great apes are more manlike than any other animals, each type is highly specialized for a lazy life in the tropical forest, and none could possibly be considered the direct ancestor of man. Instead we must go back to fossil forms of the Pliocene or

older for the stock that left the forest and returned to the ground. The oldest evidence of a manlike ape yet known is an incomplete lower jaw with two premolars and one molar tooth. It was found in the Eocene beds of Burma and has been named *Amphipithecus*.[2] The next oldest record is a jaw of *Propliopithecus* found in the Lower Oligocene beds of Egypt, along with that of the first monkey. A third genus, *Dryopithecus*, known from numerous jaws and other fragments found in Miocene beds of both Africa and Europe, is believed to be near the common line that led to the living great apes and man. Pleistocene cave deposits of South Africa have yielded the most complete remains of fossil apes, including a well-preserved skull with most of the face. These remains represent an ape, *Australopithecus*, with a brain rather larger than that of any modern type. Pleistocene beds of both Java and southern China have yielded very fragmentary remains, chiefly teeth, which indicate primates of giant size, at least twice as big as the living gorilla.

*Lilo Hess photo*

FIG. 314. Tarsier, a native of the Philippine Islands, now in the New York Zoological Gardens. About natural size.

The human stock was the last of the primates to appear. The known geologic record of man begins with the Pleistocene epoch and is the special subject of Chapter 20.

## RECAPITULATION

**Paleocene Faunas.** "The most dramatic and in many respects the most puzzling event in the history of life on the earth," G. G. Simpson has said, ". . . is the change from the Mesozoic, Age of Reptiles, to the . . . Age of Mammals. It is as if the curtain were rung down suddenly on a stage where all the leading roles were taken by reptiles, especially dinosaurs, in great numbers and bewildering variety, and rose again immediately to reveal the same setting but an entirely new cast, a cast in which the dinosaurs do not appear at all, other reptiles are mere supernumeraries, and the leading parts are all played by mammals of sorts barely hinted at in the preceding acts."

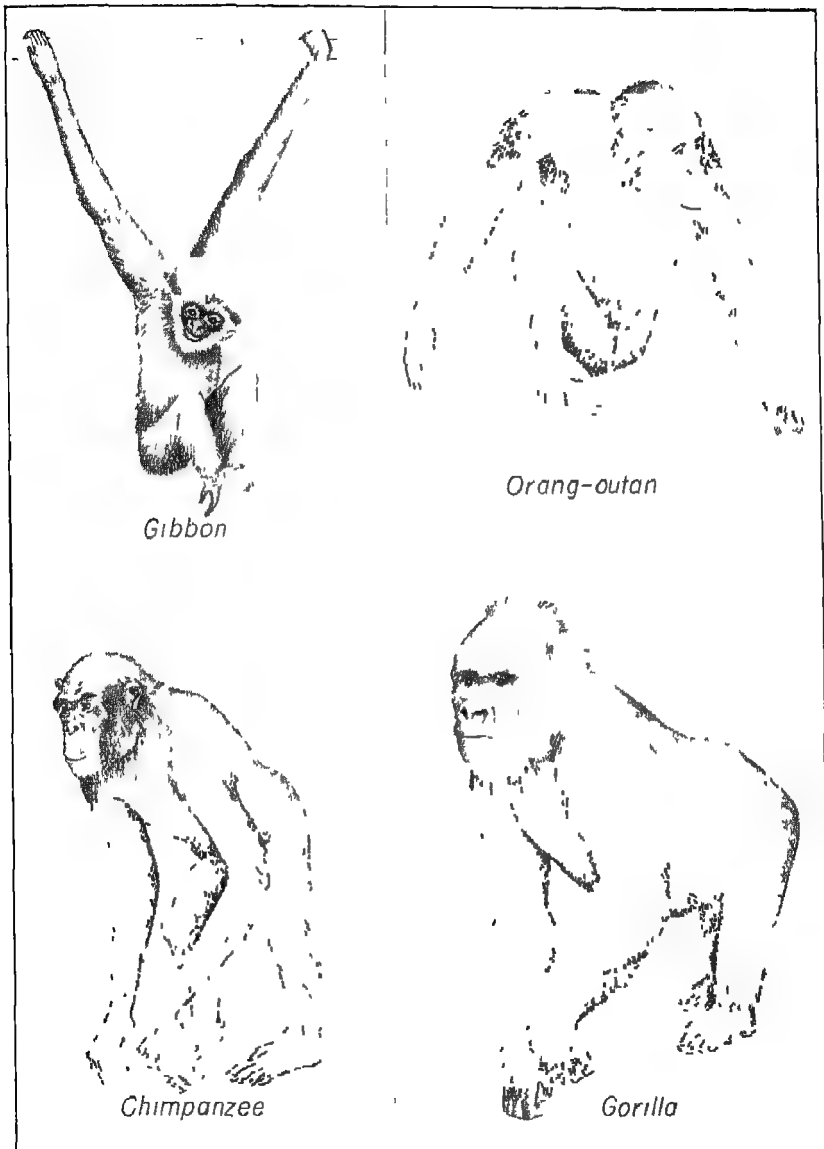



FIG 315 Manlike apes The four living types of manlike apes are shown here at the same scale The gibbon and the orang-outan inhabit southeastern Asia and the Netherlands East Indies, the chimpanzee and the gorilla inhabit the tropical forests of Africa

Clearly these Paleocene mammals came for the most part as migrants from some region (probably northern Asia) where they had been developing even before the close of the Mesozoic. Among them were holdovers of three groups already known in the Cretaceous world—multituberculates, marsupials, and insectivores. But the dominant groups—condylarths, amblypods, and creodonts—belonged to three "archaic" orders that appeared suddenly, thrived for a while, and then died out. Although these orders lived on into Eocene time and some then attained considerable size, the Paleocene species were small, the largest scarcely exceeding the size of a hog or a small bear.

With these "archaic" stocks were associated the forerunners of several orders that are still extant, notably the rodents and primates, but these were all small.

Nearly all the Paleocene mammals had long narrow heads with small braincases and long slender muzzles. They were quadrupedal, with fore and hind legs nearly equal in length. All had five toes, and the earliest known examples of each stock walked on the sole of the foot. The distinction between the marsupials and all the rest was already so complete as to suggest that the placental mammals were not direct descendants of the marsupials, but cousins descended from a common Mesozoic ancestor.

**Eocene Faunas.** The most striking feature of the early Eocene life was the appearance in considerable numbers of progressive forms ancestral to the modern orders of mammals. Among these were diminutive *horses,* small hornless *rhinoceroses,* equally small *titanotheres,* tiny *cameloids,* the first *oreodons,* squirrel-like *rodents, bats,* and small *primates.* None of these attained a considerable size, and the largest would hardly have stood waist-high to a man.

With them were associated the "archaic" mammals, some of which were far larger. *Creodonts* were the carnivores of that time, and of these some were doglike, some hyenalike, and others more catlike. Common American types reached a maximum size only about that of a modern timber wolf, though one of the latest Eocene types was as large as a great bear. The greatest of all Eocene carnivores, however, was the Mongolian *Andrewsarchus,* with a skull about 2½ feet long. The *condylarths* were common during the early half of the epoch but died out before its close. The great animals of this time were the ponderous *amblypods,* which increased gradually to their maximum bulk in *Uintatherium* of the late Eocene.

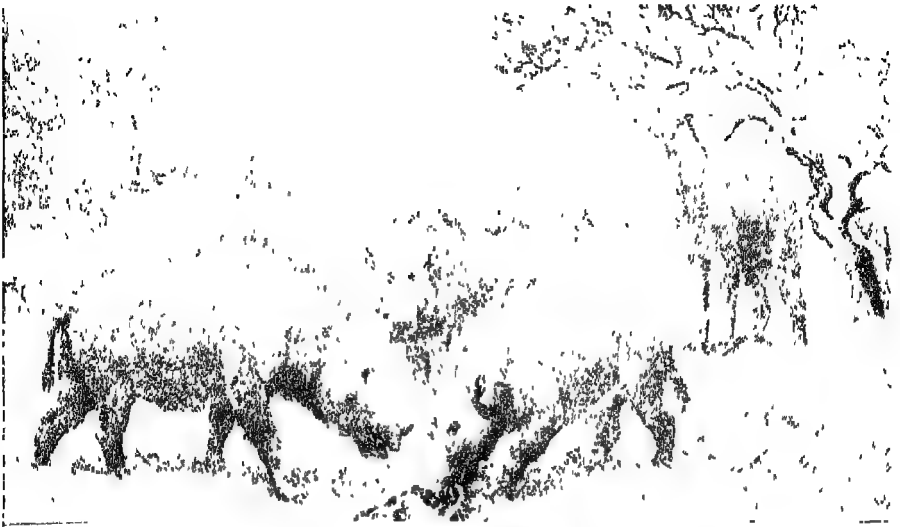
In the later Eocene occurred the first mammal adaptation to a marine life, in the form of whalelike animals (zeuglodons), whose

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*Fig. 316. Early Miocene landscape in Nebraska, showing "giant pigs" in center foreground, Moropus browsing on tree at right, and three-toed horses in middle distance at extreme left. From a painting by Charles R. Knight*

fossil bones occur abundantly in parts of our southern states, in Egypt, and in Europe. One of these, *Basilosaurus*, must have been the "sea serpent" of its time, with 4 feet of head, 10 feet of body, and 40 feet of tail! But even a mammal of this size met its match in the great sharks of those seas, the gaping jaws of one of which (*Carcharodon*) must have been about 6 feet across.

**Oligocene Faunas.** By Oligocene time, the modernized types comprised nearly the entire mammalian fauna. A single genus of creodonts remained, but amblypods and condylarths were wholly extinct, and marsupials and insectivores were as inconspicuous as they are today. In western America the *oreodons* roamed in vast herds over the plains. Three-toed horses (*Mesohippus*) scarcely larger than sheep were common. *Rhinoceroses* of several kinds were present, the largest of them being amphibious, though not related to the hippopotamus. Probably all the Oligocene species were hornless. The *titanotheres* displayed a meteoric evolution, and with the exception of the giant Asiatic rhinoceros, *Baluchitherium*, they became the largest land animals of this time before dying out abruptly about the middle of the epoch. Small camels were present, and so were peccaries and tapirs. The rodents were represented by beavers, squirrels, rab-

*Fig 317 Late Miocene landscape in Nebraska, showing at the left a group of short-legged rhinoceroses, and at the right a pair of four-tusked, long-jawed mastodons From a painting by Charles R Knight*

bits, and mice Among the carnivores there were many small *dogs*, as well as both *biting* and *stabbing cats* In the Old World the Proboscidea were beginning their career, being represented by the first mastodons, which were only about 5½ feet high Early primates had become extinct in North America, and the only known great ape was represented in Europe by a single species

**Miocene Faunas.** The Miocene was the "Golden Age" of mammals (Figs. 316, 317) The spread of the prairies and the change to more arid climate led to rapid evolution of the grazing stocks, and the formation of a Bering land bridge permitted intermigration between North America and Eurasia

Within the groups of animals already present there was a rapid expansion into new genera and species and an increase in size in many stocks The habit of feeding on the harsh prairie grasses resulted in a remarkable change in the teeth of many groups, whereby the jaw teeth became long and prismatic and continued to grow throughout life, thus counteracting the rapid wear at the crowns *Horses* now attained the size of small ponies, but the many species all had dangling side toes *Camels* were especially abundant and varied, some being little larger than sheep, while others rivaled the modern giraffe in height *Oreodons* were still very common *Rhinoceroses* of several kinds were abundant At this time the "giant pigs" reached their climax in a species (*Dinohyus hollandi*) known from Nebraska that was as tall as an ox and had a skull 4 feet long *Moropus*, the

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*Fig 318 Pleistocene landscape in Europe during the last Ice Age, with woolly mammoth in the foreground and woolly rhinoceros in the right middle distance*

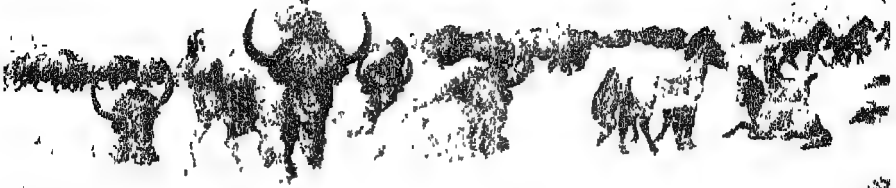
clawed ungulate, was also most common at this time *Rodents* like those of the Oligocene continued through the Miocene Of *carnivores* there were numerous wolflike dogs, as well as biting and stabbing cats There were no North American primates, but in the Old World a great ape (*Dryopithecus*), somewhat related to the gorilla, but much smaller, ranged over Europe and northern Africa The four-tusked proboscidians arrived in America

**Pliocene Faunas** The Pliocene faunas of North America are still imperfectly known because the terrestrial formations of this age are so sparsely preserved At this time there was further immigration from the Old World, bringing us the *true mastodons* *Horses* continued their rapid evolution and were represented in America by several genera, among which appeared the first single-toed horse, *Pliohippus* *Rhinoceroses* were still very abundant *Camels* continued to be among the most common animals of the plains The last straggling survivors of the oreodons were extinct before the close of the epoch

**Pleistocene Faunas.** Throughout the Pleistocene epoch North America and Europe were both inhabited by great game animals fully as varied and impressive as those of modern East Africa In the United States the *elephants* were perhaps the most impressive, for there were at least 4 species, 2 of which exceeded modern elephants in size The tall, rangy imperial mammoth of the southern Great Plains stood nearly 14 feet high at the shoulders Another species (*Mammuthus arizonæ*) was at home in the basins of Arizona and

*Fig 319 Scene in the Mississippi Valley during Pleistocene time. At the left, the American masto-*

Nevada Numerous remains of *Mammuthus columbi* and *M imperator* have been found in the uppermost beds of glacial Lake Bonneville, and these elephants must have been common in the Great Basin region until after the last of the glacial ages Throughout the forests mastodons (*Mammut americanus*) browsed in great herds (Fig 319); their remains are common in the peat bogs of the eastern states, no fewer than 217 individuals having been discovered in the bogs of New York State alone In Florida, New York, and elsewhere the remains of this species are associated with human artifacts in such a way as to indicate that mastodons survived the last ice age and may have lived until within the last several thousand years. The woolly mammoths (Fig 318) ranged widely over the glaciated areas, extending northward into Alaska and eastward across Siberia, where their skeletons and tusks are still incredibly numerous in the frozen soil, about half the present ivory of commerce being derived from this source Siberian ivory was imported into China as early as the fourth century B C, and began to be extensively transported into Europe early in the nineteenth century Between 1800 and 1850 the annual sale of tusks at the trading center of Yakutsk averaged about 18 tons, and to date not less than 46,750 pairs of tusks have been recovered in Siberia [3]

*Horses* were still common, and at least 10 species are known from North America Most of these were of the size of small ponies, but one fully equaled the greatest modern draught horse *Buffaloes* roamed the plains in great herds as they did when the white man first reached America There were at least 7 Pleistocene species, and one of these (*Bison latifrons*) was a colossal beast with a horn-spread of fully 6 feet (Fig. 319). *Camels* also were common *Wild pigs* (pec-

AMERICAN MUSEUM OF NATURAL HISTORY

*don, center, the Royal bison, right, the wild horse, Equus scotti. From a mural by Charles R. Knight*

caries), now confined to Texas, Mexico, and Central America, then ranged over the United States.

*Carnivores* were abundant and varied, including species of such modern types as the wolves, foxes, pumas, lynxes, raccoons, badgers, otters, skunks, and weasels. In addition, there were extinct types of which the great saber-tooth (*Smilodon*) was perhaps the most striking. Another great cat (*Felis atrox*), also known from the tar pits of Rancho La Brea, was very much like the modern lion in form and size. The great wolf (*Canis dirus*) which was so common in southern California exceeded in size any modern American canines. True bears apparently made their appearance in America at this time as immigrants from the Old World.

One of the most striking elements of the Pleistocene fauna was due to the immigration from South America of the *glyptodonts* and the great *ground-sloths*. These both reached Texas in the Pliocene, and the latter spread over the United States in the Pleistocene. The ground-sloths (Fig. 24, p. 43) were clumsy beasts with the bulk of an elephant, but they were short-legged and curiously club-footed—their ancestors had lived so long in the trees and had developed such long, curved claws that it was impossible for them to walk on the bottoms of the feet when they became too heavy to live longer off the ground. These creatures are common fossils in the tar pits of southern California, and at least one genus (*Megalonyx*) ranged eastward to the Atlantic States. A claw of this form was discovered in a cave in Virginia by President Jefferson, who was the first to describe and name the genus but thought it to be a mighty lion.

North and South America were separated throughout Cenozoic time until they became united by the present Isthmus of Panama in the

late Pliocene Just before this connection, South America had 29 families of mammals and North America 27, but with 2 doubtful exceptions they had no families in common Shortly afterward, in the Pleistocene, they had 22 families in common, 7 of South American origin and 14 of North American origin and 1 doubtful Those emigrating to South America included the mastodons, horses, tapirs, camels, and peccaries, those coming in the opposite direction included the ground-sloths, armadillos, and glyptodonts [1]

Another striking element of the Pleistocene faunas was supplied by the arctic animals that migrated southward during the glacial ages For example, the musk-ox is recorded as far south as Arkansas and Utah, while in Europe the reindeer, the woolly rhinoceros, the woolly mammoth, and the arctic fox ranged southward into France and Poland

There were no primates in North America until primitive man reached here from the Old World Although evidence of the presence of early man in America has been claimed repeatedly, it is still scanty On the other hand, savage races were present in Europe and in eastern Asia and northern Africa throughout much if not all of the Pleistocene epoch The geologic history of man is reserved, however, for a special chapter

In Europe, the Pleistocene fauna of the warm interglacial ages included most of the types of great game animals now found in Africa Such, for example, were the lion, the rhinoceros, the hippopotamus, the elephants, antelopes, and lesser animals

## Contemporary Life

**Spread of the Prairies.** Forests were essentially modern at the beginning of the Age of Mammals Most of the genera of hardwood trees had appeared during the Cretaceous period, and their subsequent evolution has been in the main a matter of specific details On the contrary, the development of the grasses during this era was one of the great milestones in the history of life, and for the evolving mammals its importance can hardly be overemphasized It is this stock, for example, that includes not only the forage plants but also the cereals—notably wheat and rice and oats and corn—that provide the basic food supply for the modern world

Grass is poorly adapted for preservation, and almost no direct evidence of its early history is known However, it contains an

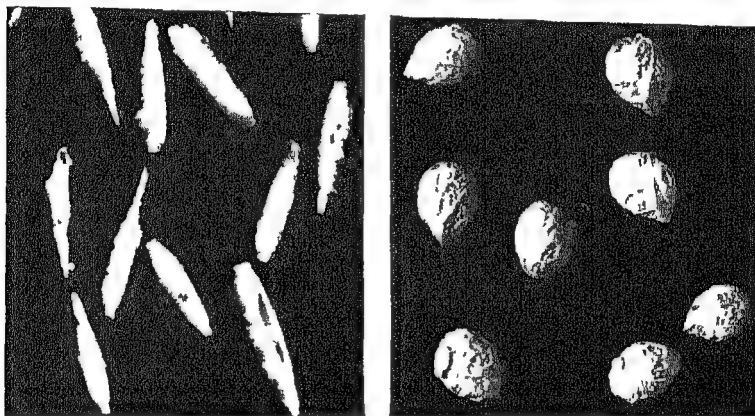
appreciable amount of silica and tends to wear out the grinding teeth of the grazers, that is, grass-feeders To compensate for such wear, the modern plains mammals have high-crowned cheek teeth that grow at the roots throughout life (Fig 292) Pre-Miocene representatives of each of these groups, like the modern forest-dwellers that browse on more succulent leaves, had low-crowned cheek teeth It appears evident that the high-crowned grinding teeth are a direct adaptation to a grazing habit, and since this specialization began early in the

M K Elias

FIG 320 Seeds of grasses and other herbs Left, the spear grass, *Stipidium commune*, from the Pliocene (Valentine formation) near Wray, Colorado, right, the borage herb, *Biorbia fossilia*, from the Pliocene (Ash Hollow formation) near Castle Rock, Kansas

Miocene, it is inferred that prairie grass had then, for the first time, become widespread About 1940, fossil grass seeds were discovered in some of the sandy beds of western Nebraska,[5] and it was soon found that they are abundant over the High Plains region in beds ranging from Mid-Miocene to late Pliocene date (Fig 320) Careful search in the underlying early Miocene and Oligocene deposits of the same region has thus far been in vain

Other herbaceous plants are still imperfectly known, but roses with characteristic leaves and thorns have been found in the Oligocene, and unmistakable leaves and seeds of the grape occur in Eocene and later rocks of both Europe and America Petrified grape vine is known from the Miocene beds of Nevada

**Modernization of the Invertebrates.** The invertebrate animals, like the forest plants, had practically accomplished their present evolution before Cenozoic time A few of the modern species were al-

ready living in the Eocene epoch, and many were extant in the Miocene

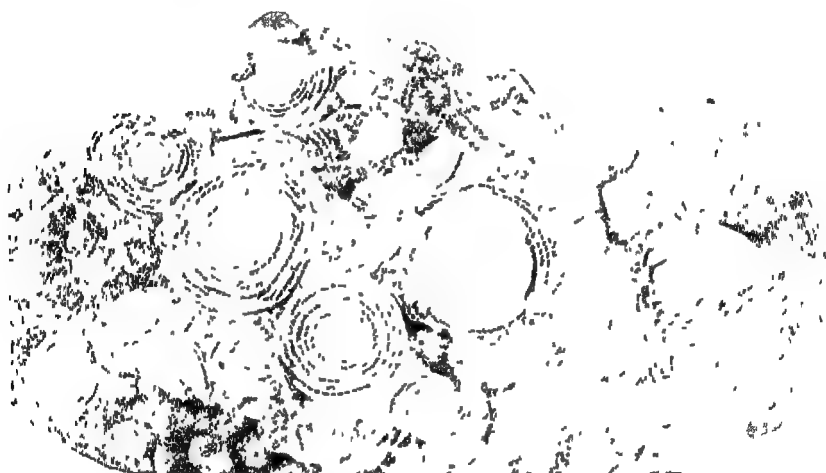
Special note should be made, however, of the *nummulites*, a family of very large Foraminifera having discus-shaped, or coin-shaped, multichambered shells (Fig 321) They were extraordinarily abundant in the seas of the Mediterranean region during Eocene and Oligocene time, and their shells contributed largely to the *nummulite lime-*

*Yale Peabody Museum*

FIG 321 A chunk of nummulitic limestone from one of the pyramids of Egypt Herodotus (about 450 B C) alluded to this stone as an instance of petrified animals Natural size

*stones* that are widely distributed in southern Europe, northern Africa, and the Himalayan region, where the Eocene is still commonly spoken of as the "nummulitic period" Such shells are less common in the American Eocene but do appear abundantly in the upper Eocene and Oligocene of Florida and the Caribbean region

**Decline of the Reptiles** With the extinctions at the close of the Mesozoic, the reptile dynasty collapsed Turtles, crocodiles, and lizards lived on about as they are today, except that large land turtles and alligators were more widely distributed during the warmer times Fossil turtles are abundant in the badlands of Oligocene and Miocene age Enormous species, large enough to stand waist-high to a man, were common in Florida in Pleistocene time As noted before, alligators occur frequently in the Eocene and Oligocene deposits

as far north as Wyoming and the Dakotas Snakes are first recorded in the Late Cretaceous and therefore existed throughout the Cenozoic, but, because of their retiring habits and their delicate skeletons, they are always rare fossils An Eocene species related to the modern boa constrictor and estimated to be 35 feet long was found recently in Patagonia

**Birds.** Modern types of birds, all toothless, appeared in the Eocene, and even at that early date most of the present orders were represented Such, for example, were the eagles, vultures, pelicans, quail, and various shore birds All these stocks persisted through the Cenozoic, though fossil remains are, in general, rare because the bird skeleton is fragile

Nearly all the continents at one time or another during the Cenozoic had large, flightless birds One of these (*Diatryma*), known from the early Eocene beds of Wyoming, stood nearly 7 feet high and had a very stout neck and a head almost as large as that of a horse Another (*Phororhacos*), found in the Miocene of the Argentinian pampas, stood 7 to 8 feet high and had a very massive skull 23 inches long with a strongly hooked beak (Fig 322) It was undoubtedly the greatest of all birds of prey The largest bird, however, was an ostrich-like form, *Dinornis,* that lived into historic time in New Zealand and was exterminated by the Maoris only a few centuries ago This enormous bird stood about 10 feet high and was therefore more than 2 feet taller than the greatest living ostrich Still another giant (*Aepyornis*) of Madagascar laid the largest known eggs, which normally measured 13 inches long and 9 inches across Discovery of the eggs of this bird by early navigators inspired the thrilling tales of the roc told by Sindbad the Sailor in the *Arabian Nights*

Fig 322 *Phororhacos*, a giant flightless bird of the Miocene of Patagonia Drawn by Charles R Knight From Lucas, *Animals of the Past*

## References

[1] *Paleocene*, by Glenn L Jepsen In *Land Mammals of the Western Hemisphere*, by W B Scott 2d ed, 1937, The Macmillan Co, p 230

[2] *Fossil Mammals from Burma in the American Museum of Natural History*, by E H Colbert Bulletin of the American Museum of Natural History, Vol 74, Art VI, 1938, p 290

[3] *Carcasses of the Mammoth and Rhinoceros Found in the Frozen Ground of Siberia*, by I P Tolmachoff Bulletin of the Geological Society of America, Vol 39, 1928, pp 294–296

[4] *Mammals and Land Bridges*, by George G Simpson Journal of the Washington Academy of Sciences, Vol 30, 1940, pp 136–163

[5] *Tertiary Prairie Grasses and Other Herbs from the High Plains*, by Maxim K Elias Geological Society of America, Special Paper 41, 1942

## Collateral Reading

*The Age of Mammals*, by Henry F Osborn 635 pages The Macmillan Co, New York, 1910 Rev ed, 1921

An exhaustive but readable and well illustrated volume

*A History of Land Mammals in the Western Hemisphere*, by W B Scott 786 pages The Macmillan Co, New York Rev ed, 1937

*O C Marsh Pioneer in Paleontology*, by Charles Schuchert and Clara Mae LeVene 541 pages Yale University Press, New Haven, 1940

An account of early exploration in the West, of the discovery of three-toed horses, and of the growth of vertebrate paleontology

*Man and the Vertebrates*, by Alfred S Romer University of Chicago Press 3rd ed, 1941, pp 1–405

## Chapter 20

# THE COMING OF MAN

### Prehistoric Documents

**Artifacts.** The American pioneers found the Indians using stone implements instead of metal Flint provided tips for their arrows and blades for their tomahawks, and stone mortars served as mills for the grinding of maize To these early settlers there was no mystery attached to the finding of such carefully shaped stones where the Indians had once pitched their camps

Similar stone implements found in western Europe, however, were regarded with strange superstition throughout the Middle Ages, and were commonly thought to be thunderbolts The civilized world at that time had little contact with primitive peoples, and, moreover, it was completely dominated by the belief in a Special Creation that left no place for extinct races of men antedating the present civilization Yet stone implements are abundant in parts of Europe and were commonly collected as curios after the Renaissance, and we find Olaf Worm, a Danish authority on such objects, writing in 1655 that "they are commonly supposed to fall with the lightning from the sky," though "opinions differ as to their origin, since some believe they are not thunderstones but petrified iron implements, seeing they resemble the latter in shape so closely." And as late as 1802, Thorlacius, writing of stone artifacts discovered in burial mounds, concluded that "the objects found in the mounds are nothing else than symbols of the weapons employed by the Gods of Thunder in chasing and destroying evil spirits and dangerous giants They could not be ordinary tools and weapons as these have been made of metal since the earliest times"

It now seems strange that a belief so fantastic could have persisted for 300 years after Europeans had encountered the American Indians using stone implements, it sprang from the assumption that such savages were pre-Noachian degenerates who had wandered far from the original center of civilization and had lost the art of working

metal. Occasional thinkers, far ahead of their time, had, indeed, realized the true meaning of archeological remains since before the beginning of the Christian era, but it was not until within the last century that these remains were generally accepted as evidence of prehistoric races. Even then, no one considered the possibility that they might represent the work of extinct *species* of man until after Darwin's *Origin of Species* had paved the way for a belief in the gradual evolution of man from the lower animals.

The appreciation of the true meaning of stone artifacts was first developed in Scandinavia shortly after 1830. It began with the creation by the Danish Government of a scientific commission to study the refuse heaps and shell mounds that had already attracted attention in the region. As a result of this project, extensive collections were assembled at the Royal Museum in Copenhagen and were studied with respect to their stratigraphic occurrence in the mounds. On this basis, Thomsen, the director of the Museum, in 1837 proposed a chronology of human culture divided into the *Stone Age*, the *Bronze Age*, and the *Iron Age*.

Man undoubtedly advanced through this sequence of cultures on the way to civilization, but in western Europe the making of bronze and the smelting of iron had been mastered while aborigines in many parts of the world were still using crude stone implements. Thus the Iron Age in Europe was contemporaneous with the Stone Age in many other parts of the world. Thomsen's chronology is therefore only applicable locally.

The tools and other implements used by a people represent its *culture*. The style of workmanship changed with time during the Stone Age, just as it does in the modern world, and as it is easy to distinguish the relative ages of a collection of colonial flintlocks and one of modern high-power rifles, so it is also possible to distinguish different cultures of stone implements. Accordingly, other workers, following Thomsen, further subdivided the Stone Age into three stages, Eolithic, Paleolithic, and Neolithic, based on the type of workmanship displayed. Of course, these subdivisions also have only local value as time units.

The first tools used by man were doubtless those accidentally shaped by nature to fit his hand, such as sharp-edged chips of flint that he could use to scrape skins or to fashion wooden tools. Such stones, which he picked up and used without modification, are known as *eoliths* (Gr. *eos*, dawn, + *lithos*, stone). Showing evidence of wear but not of conscious shaping, they represent the lowest stage of human

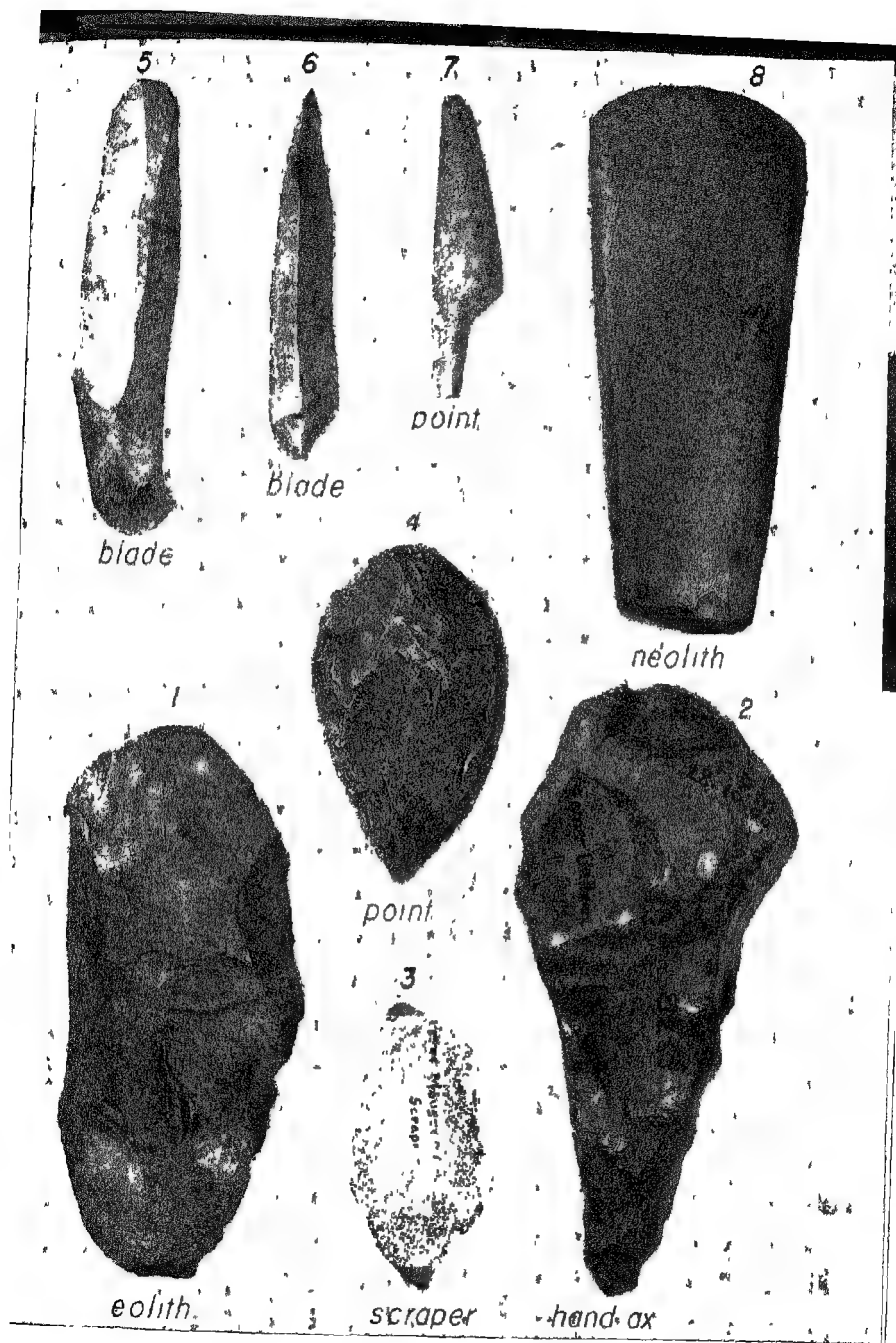



*Fig 323 Stone implements Number 1 is an eolith, 2–7 are paleoliths, and 8 is a neolith Number 1 represents a pre-Chellean culture, 2, a Chellean culture; 3 and*

culture and are found in formations as old as the late Pliocene (Fig 323)

Eventually man learned to flake off pieces of stone and to shape them, by chipping, into scrapers, hand axes, spear heads, and other useful tools This was an art slowly acquired through countless generations of trial and experiment by primitive peoples whose lives often depended on the quality of their weapons Such artifacts, shaped by chipping alone (Fig 323), are known as *paleoliths* (Gr *palaios,* ancient, + *lithos,* stone), and cultures represented by such implements characterized the *Paleolithic* age, which endured in Eurasia until a few thousand years ago

In Europe some of the prehistoric peoples advanced a stage farther in the making of stone implements which they shaped and sharpened by grinding and polishing against natural abrasive stones Such objects, known as *neoliths* (Gr *neos,* recent, + *lithos,* stone), are found only in deposits younger than the last glacial till in northern Europe, and they mark the highest Stone-Age culture, attained in Europe shortly before the discovery of the use of copper

Metals first began to replace stone for implements about 5000 B C, copper and bronze (an alloy of copper) being employed sooner than iron because they are easier to smelt The art of working copper began apparently in Egypt and had spread to Chaldea as early as 4500 B C., but it was unknown in Europe until about 1500 B C Iron implements were developed by the Egyptians as early as 3000 B C and iron swords were in use in Greece between 1400 and 1300 B C, but the iron industry did not spread to central Europe until about 800 B C.

The succession of cultures in Europe is shown in the table of human prehistory on p 504

**Human Fossils.** Prehistoric human remains are, for obvious reasons, among the rarest of fossils With his superior intelligence, man generally avoided such common catastrophes as miring and drowning Of course this did not reduce the number who died, but it lessened the chances for burial where preservation would be likely Furthermore, funeral rites, observed by man since very remote times, commonly resulted in destruction of the remains, whether the funerals involved cremation, elevation on scaffolds, or burial in shallow graves, since the graves were generally placed on elevated mounds where both weathering and erosion are active

A fortunate exception was provided by the cave dwellers, who took refuge in caverns or overhanging shelters along the river bluffs of

G. G. MACCURDY.

*Fig. 324. Rock shelter of Les Eyzies, Dordogne, France. The re-entrant along the middle of the cliff was occupied by Paleolithic man.*

Europe and parts of Asia during the late Pleistocene, finding there a shelter from the inclement weather and a refuge from the powerful carnivores of the time (Fig. 324). These peoples commonly buried their dead in the caverns where they also would be safe from the ravages of wild beasts—and, fortunately for us, they surrounded them with food and weapons intended for use in the future life. Such cave burials therefore give us not only the physical characters but also the culture which was actually used by the individual preserved. Thus we find a tie-up between the human fossils, which are rare, and the definite cultures of stone implements, which are widely scattered and almost indestructible. Such burials also commonly include two or more individuals, thus giving us a record of both sexes and of the young as well as the old.

Until it was admitted that extinct races had preceded the present inhabitants of Europe, human fossils were not recognized as such and, if observed, were considered merely the remains of buried dead. But in 1857 there was found in the Neander Valley near Dusseldorf, Germany, a type of skull obviously unlike modern man in many charac-

teristics After the publication of Darwin's *Origin of Species* in 1859, this skull was soon seen to be the record of an extinct species far more apelike than any living men, and it became the type of the Neandertal race During recent years, the present interest in human antiquity has led to increasingly numerous discoveries, until approximately 100 localities have now yielded human fossils. The majority of these are associated with caves and rock shelters, but several are in river terraces or lake deposits and record accidental deaths and natural burial

**Dating the Record** Paleolithic man was a hunter, procuring both food and clothing from the game he could kill His weapons were adapted to this end, and his camp sites were surrounded with the bones of his prey As he lived through the last ice age in Europe, his environment changed greatly with the advance and retreat of the glaciers In addition to the climatic differences between glacial and interglacial ages, he experienced great changes in his food supply During the last glaciation, for example, an arctic fauna ranged southward to the Mediterranean, including the arctic fox, the woolly mam-

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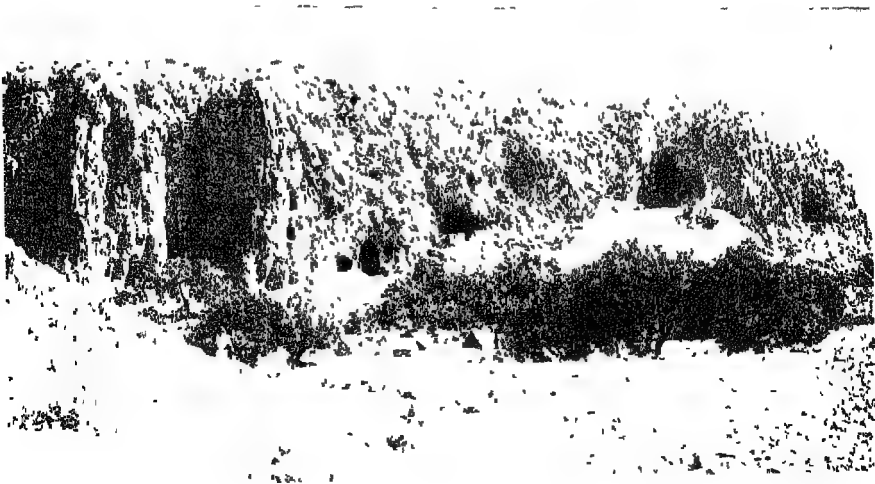
*Fig 325 Cave of the Kids in the Valley of the Caves (Wady el Mughara) in Palestine Before this group of caves there is stratified refuse about 70 feet thick, a succession of eleven prehistoric cultures ranging from the pre-Acheulian to the Bronze Age*

moth, and vast herds of reindeer. The last named became at that time the chief source of human food and clothing. But during the preceding interglacial age the reindeer had been restricted to the Arctic, and temperate and subtropical game had spread northward over Europe, including, among other creatures, the lion, the hippopotamus, the elephant, and great herds of wild horses. At that time the horse was the chief object of the chase.

Thus, throughout the million years or so represented by the Stone Age in Europe, the steady evolution of the mammalian faunas was

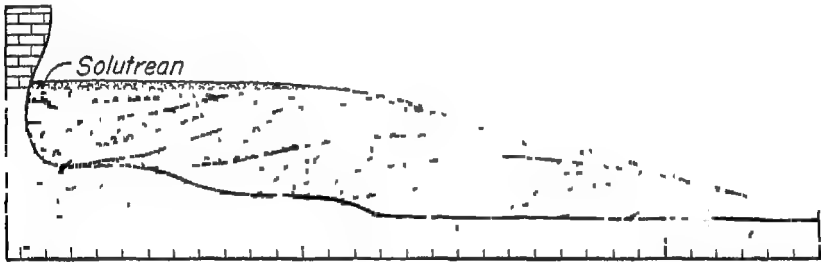



FIG. 326. Diagrammatic section of the stratified deposits before the rock shelter of Laussel, France, showing a succession of five distinct cultures. The layers bearing artifacts are stippled, and the cultures are named. Adapted from G. G. MacCurdy, *Human Origins* (D. Appleton and Company).

accentuated by extensive north and south migrations induced by the glaciation. Accordingly, the different stages of the Pleistocene, represented south of the limits of glaciation by outwash and terrace gravels, contain quite distinctive mammalian faunas. The succession of faunas, worked out from many occurrences, provides the key for dating the human records.

Fortunately for us, primitive man had little notion of sanitation, and camp refuse was thrown away to accumulate over the slope below many shelters that were long inhabited. Of course this refuse included broken or discarded artifacts as well as bones. The most-favored camp sites were used in succession by different peoples throughout much of Paleolithic time, and the refuse of each in turn accumulated to form a roughly stratified deposit. One of the thickest and most complete records known is that about the Cave of the Kids in the Valley of the Caves in Palestine (Fig. 325), where stratified refuse about 70 feet thick includes distinct layers representing eleven different cultures, ranging from early Paleolithic time to the Bronze Age (*cf.* Fig. 326).

In dating actual human fossils, it is always necessary to make sure that the bones have not been artificially buried in layers of sediment of much older date

A CALENDAR OF HUMAN HISTORY

(From *Glacial Geology and the Pleistocene Epoch*, R F Flint)

| Geologic Time Units | | | Dates in Years, B C (*estimated*) | Cultural Stages | | | Types of Fossil Man | |
|---|---|---|---|---|---|---|---|---|
| | *North America* | *Europe* | | | | | | |
| Pleistocene epoch | Wisconsin glacial age | Fourth glacial age | 5,000 | Age of Metals | | | Homo sapiens | Modern man |
| | | | 6,500 | Neolithic | | | | |
| | | | | Mesolithic | | | | |
| | | | 15,000<br>55,000<br>100,000 | Paleolithic | Late | Azilian<br>Magdalenian<br>Solutrean<br>Aurignacian | | Cro-Magnon man |
| | *Sangamon interglacial age* | *Third interglacial age* | 225,000 | | Middle | Mousterian | *Neandertal man* | |
| | Illinoian glacial age | Third glacial age | 325,000 | | Early | Acheulian<br>Levalloisian | | |
| | *Yarmouth interglacial age* | *Second interglacial age* | 600,000 | | | Chellean<br>Choukoutienian<br>Clactonian | *Heidelberg man*<br>*Peking man*<br>*Pithecanthropus*<br>*Swanscombe man* | |
| | Kansan glacial age | Second glacial age | 700,000 | | | | | |
| | *Aftonian interglacial age* | *First interglacial age* | 900,000 | | | Pre-Chellean | *Piltdown man* | |
| | Nebraskan glacial age | First glacial age | 1,000,000+ | | | | | |
| Pliocene epoch | | | | Eolithic | | | | |

## MEN OF THE OLD STONE AGE

**Flint Workers of England.** The most ancient relics of mankind are found in England Near the city of Ipswich, about 65 miles

northeast of London, the upper Pliocene beds include seven layers that have yielded abundant eoliths, now accepted by archeologists as the implements of primitive man. About 60 years ago there was also found here a stiletto made of a deer horn. The locality has particular interest because the flint implements lie under a fossiliferous marine bed that proves conclusively the Pliocene age of the deposit.

Slightly younger deposits (early Pleistocene) of similar nature are found at Foxhall, a few miles northeast of Ipswich, and there the flints are associated with charred wood, suggesting that the ancient flint workers had already discovered the use of fire. At Cromer, still farther northeast of London, there is another bed (the Cromer Forest bed) of early Pleistocene age, from which large but crudely chipped flint implements have been recovered. In none of these localities have any skeletal remains been found, but the crude implements indicate clearly the presence of man in England at the close of the Pliocene and early in Pleistocene time.

**Pithecanthropus.** The most discussed of all human fossils was discovered in 1891 by Eugene Dubois, a Dutch army surgeon stationed on the island of Java. He had opened a quarry for vertebrate fossils in a 3-foot bed of gravel exposed in the bank of Solo River, and there he came upon several human bones—a skull cap, a left thigh bone, fragments of nasal bones, and three teeth. Although each bone was isolated, and the thigh bone was found almost 50 feet from the skull, Dubois assumed that they belonged to one species if not to one individual.

The skull cap was remarkably thick, the brow ridges very massive, and the forehead low and receding. The brain of this skull, estimated to have had a volume of 900 cubic centimeters, is intermediate in size between that of the largest apes (about 600 cubic centimeters) and the average for the lowest types of living men (about 1240 cubic centimeters). Moreover, the scars of attachment for the great neck muscles at the base of the skull clearly imply that the head was carried forward, as in the apes, instead of being well balanced on the neck, as in modern man.

Soon after discovery, this find was hailed as a "missing link" between the apes and man and was given the name *Pithecanthropus* (Gr. *pithecos*, an ape, + *anthropos*, a man). Almost at once it became a subject of controversy. Skeptics argued that this was an abnormal individual, perhaps an idiot, but statisticians pointed out the extreme improbability of an abnormal individual being the sole one to be

preserved and discovered All uncertainty was cleared up by the extensive and careful restudy of the area by Weidenreich between the years 1935 and 1940, which brought to light three additional skulls The last and most important of these (Fig 327) includes the upper

Fig 327 *Pithecanthropus erectus* Skull No IV, found by Von Koenigswald in 1939, as restored by Franz Weidenreich The darker parts are actual bone, the lighter parts are restored by comparison with other skulls of the same species

jaw, part of the lower jaw, and several teeth, along with the posterior and basal part of the braincase It is somewhat larger and more massive than the original skull and is believed to be that of a male, whereas the original was female These skulls fully confirm the interpretation previously made of the brain size and the shape of the head and face of *Pithecanthropus*, and prove beyond possible doubt that this is a well-defined but primitive human type On the other hand,

the thigh bone found by Dubois is now believed to belong to a different and much younger species.

The small brain, low forehead, heavy brow ridges, protruding mouth, and receding chin give the skull a striking resemblance to that of a great ape, as shown in Fig. 328, yet the brain is far larger than that of any great ape, the tooth line is even, the canine teeth are relatively small, and the dentition is in all respects human rather than simian. There is no longer any doubt that *Pithecanthropus* was human. Unfortunately no limb bones are yet known.

Fig. 328. Skulls of modern gorilla (left), *Pithecanthropus* (center), and modern man (right). The apelike character of *Pithecanthropus* may be seen in the low forehead, heavy brow ridges, protruding jaws, and chinless profile. After F. Weidenreich in *Natural History*.

The geologic date of *Pithecanthropus* was at first thought to be late Pliocene or early Pleistocene, but it is now known to be about Mid-Pleistocene.[1] It is difficult to correlate the deposits in Java with those of a definite glacial or interglacial age because they are in the tropics, far from scenes of glaciation. However, a large fauna of other mammals has now been recovered from the gravel bed that yielded the human fossils, and it clearly indicates a Mid-Pleistocene date.

Six faunal zones are now known in the Pleistocene deposits of Java, and all the remains of *Pithecanthropus* are from a single one of these, the so-called Trinil horizon. Other human remains of more modern type are found in some of the higher zones.

**Peking Man.** A series of discoveries in 1928 and 1929 near Peking, China, brought to light another race closely allied to *Pithecanthropus* and representing the same stage of human evolution. The remains were found amid cave deposits of Chicken Bone Hill (Chou Kou Tien) about 30 miles south of Peking. At the time of habitation the site was a spacious limestone cavern, but it has since been filled with debris fallen from the walls or washed in from above and cemented in part

with travertine. The race has been named *Sinanthropus pekingensis* (Gr *Sinos*, China, + *anthropos*, man)

Once the great significance of this primitive human race was perceived, systematic exploration of the deposits was undertaken with the joint support of the Geological Survey of China and the Rocke-

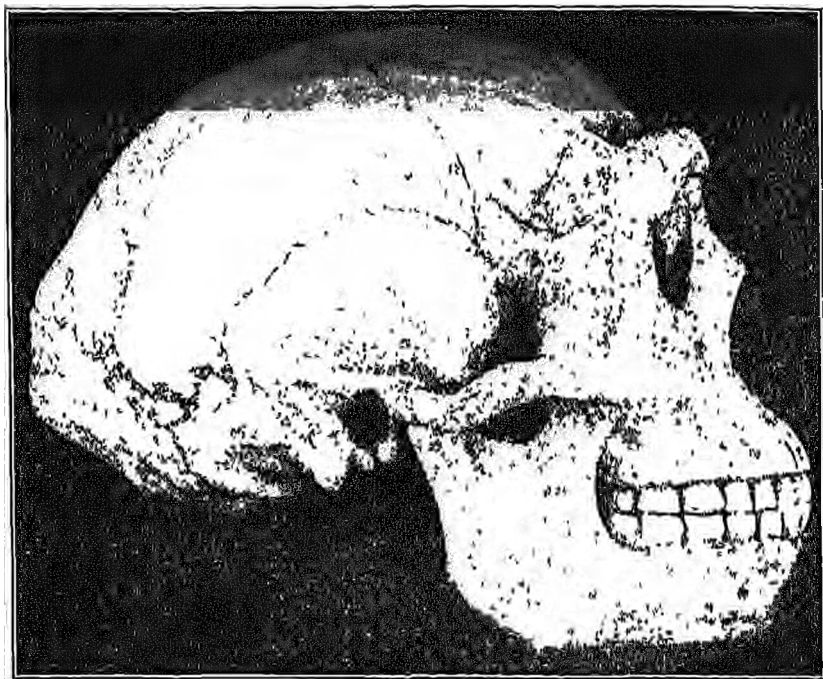



**Fig 329** Model of the skull of Peking man by Franz Weidenreich Note the low forehead, the heavy brow ridges, the protruding mouth, and the receding chin About ½ natural size.

feller Foundation, and for more than a decade, 50 to 100 technicians and laborers worked continuously at the excavation As a result, about 40 individuals have now been recovered, including men and women and children In addition, a large fauna of contemporaneous mammals has been found, many of which represent the prey that Peking man brought home from the chase About seven-tenths of all these are deer, suggesting that this was the chief animal hunted

The human remains (Fig 329) are nearly all skulls and lower jaws, though a few limb bones have been found The absence or rarity of other skeletal parts, as well as evidences that each skull had been

broken in a peculiar way before burial, suggests that these are the remains of cannibalistic rites

As in *Pithecanthropus,* the chin is receding, the forehead very low, the brow ridges over the orbits massive, and the jaws protruding All these features, and many other technical details, are decidedly apelike characteristics and indicate plainly that Peking man was much closer to our simian ancestors than any modern races The limb bones prove, nevertheless, that he walked erect. The capacity of the braincase ranges from 850 to 1220 cubic centimeters, but in the three best preserved skulls is about 1000 cubic centimeters (Fig 329)

Associated with the skeletons have been found charred animal bones and layers with charcoal debris, ranging through a thickness of 20 feet of deposits It is therefore clear that these people used fire There have also been found with them more than 2000 crude artifacts of the Chellean cultural type, made from greenstones and vein quartz These stone implements include choppers, scrapers, gravers, and awls Some of them were evidently used also for fashioning weapons from animal bones, such as the daggers made from deer antlers In other words, *Sinanthropus* was already man, and was able to organize his life so as to select intelligently the materials useful for fuel, weapons, and tools, besides being a successful hunter of animals [2]

Although believed at first to be of Early Pleistocene age, the remains of *Sinanthropus* are now dated by the associated mammals as Middle Pleistocene

**Neandertal Man** Best known of all the extinct species of man is *Homo neandertalensis,* who inhabited the caverns of western Europe during the last interglacial age and part of the last glacial age The original discovery of this race was made in the Neander Valley near Dusseldorf, Germany, whence the name Although found the previous year, this remarkable skeleton was first described in 1858, the year before the publication of Darwin's *Origin of Species* Its striking characteristics and the timeliness of the discovery led to an immediate appreciation of the significance of the Neandertals as a species far more apelike than any living men

Since 1858, several entire skeletons have been recovered, and incomplete remains of many men, women, and children of the Neandertal race have been found in the caves and rock shelters of Belgium, France, Italy, Spain, Croatia, Crimea, and Palestine Their stone implements (the Mousterian culture), moreover, are found scattered throughout western Europe and farther eastward in Asia Minor, North Africa, Syria, northern Arabia, Iraq, and even in China Among the

striking Neandertaloid discoveries of the last few years may be mentioned the skeleton at Broken Hill, Rhodesia, that near Galilee in Palestine, and others at the Cave of the Kids near Mount Carmel, Palestine From these abundant remains it is possible to present an adequate picture of the racial characteristics and the culture of these interesting people

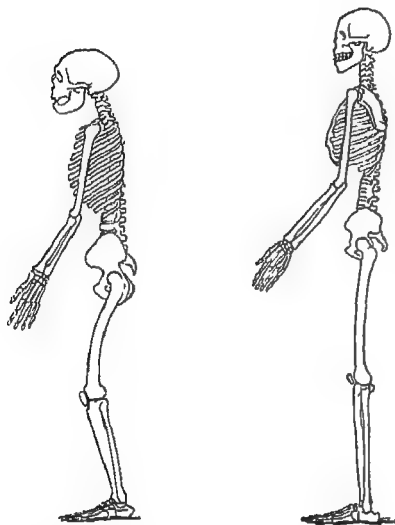



FIG 330 Skeletons of Neandertal man (left) and that of a living Australian, showing contrast in posture After Boule, from Woodward, British Museum *Guide to Fossil Man*

The Neandertals (Fig 331) were stocky and short of stature, rarely exceeding 5 feet 4 inches Although they stood upright, their carriage was more like that of a great ape than is that of living man, because the spine lacked the fourth or cervical curvature and the thigh bones were sigmoidally curved in compensation The head accordingly was carried far forward, and the body had a slouched appearance (Figs 330, 331) Both hands and feet were large, and the great toe was offset against the rest, as in the great apes

The head differed from that of modern man in the very low forehead, heavy brow ridges, and receding chin (Fig 333) The face was undoubtedly big-featured and brutal Nevertheless the brain was approximately equal in size to that of modern man (1400 to 1600 cubic centimeters), the braincase being low at the front but large in the back and lower part It has been inferred from the proportions of the brain that the species was deficient in the higher qualities of reasoning and association, and probably less capable than modern man in social organization It must be remembered, however, that Neandertal man dominated all Europe during the last interglacial age and the early part of the last glacial age, a period estimated to exceed 100,000 years

The Neandertals made fairly good stone implements, and they also knew how to kindle a fire, for hearths have been found in their cave abodes In at least two instances the skeletons have been found in their original burial places, where they had been laid away with im-

plements, paints, and food, indicating that the race held a belief in immortality, and buried the dead with ceremonial rites

*Chicago Natural History Museum*

Fig 331 Old Man Neandertal Front and side view of a restoration by Blaschke Note the slouched posture and compare with Fig 330

Among the stone implements of these people, the hand ax, scraper, and point are most characteristic Flint-tipped spears were used, but there is no evidence that Neandertal man used the bow and arrow In

view of his relatively feeble weapons, it is remarkable that he was a successful hunter of big game, including the bison, cave bear, horse, reindeer, and mammoth, all of which inhabited Europe during his reign

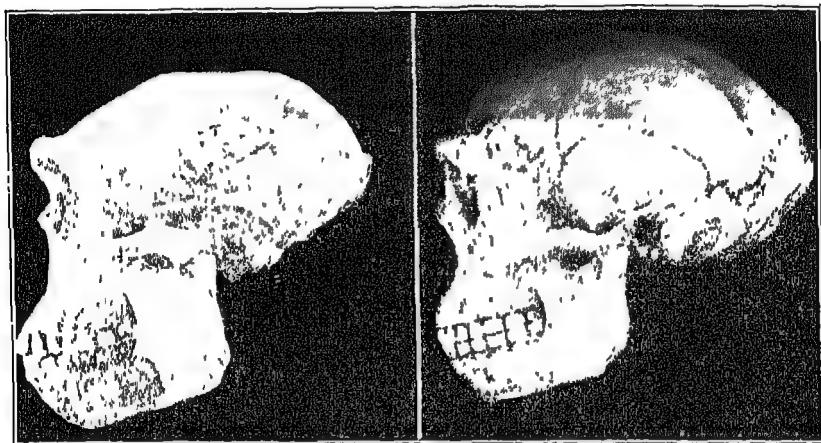
In his physical make-up, Neandertal man, like the species of the earlier Pleistocene, retained many primitive characteristics pointing clearly to his simian ancestry He was replaced with relative suddenness by the modern species, *Homo sapiens*, about the middle of the last

*American Museum of Natural History.*

FIG 332 Skulls of *Pithecanthropus* (left) and Peking man (right), for comparison with those of Neandertal and Cro-Magnon man From models by Franz Weidenreich

glacial age, and may have perished without contributing to the modern races of mankind, though it is possible that some existing stocks, like the aboriginal bushmen of Australia, still carry a mingling of Neandertaloid blood

**The Cro-Magnons.** Some time during the last glacial age, a superior race of men appeared in southern Europe, quickly replacing the Neandertals They had high foreheads, well-defined chins, and large brains, and clearly belong to the modern species, *Homo sapiens* They have been called the Cro-Magnon race for the original discovery of five skeletons at the rock shelter of Cro-Magnon in the French village of Les Eyzies in Dordogne (Fig 324)

The original find included the skeletons of an old man, two young men, a woman, and a child Numerous other remains have since come to light, so that the race is now known from many skeletons and associated stone implements and other evidences of culture and art

Among the notable occurrences is that at Předmost, Moravia, which was a mass burial including fourteen complete skeletons and fragments of others. The ancient camp site at Solutré, France, has also yielded several skeletons besides abundant artifacts and vast numbers of skeletons of the wild animals, chiefly horses, upon which these people fed after the ice had retreated and the reindeer was gone from southern Europe. The caverns of the Dordogne Valley and those

*American Museum of Natural History*

Fig. 333. Skulls of Neandertal man (left) and Cro-Magnon man (right), from models by J. H. McGregor.

about Grimaldi on the Italian frontier have likewise yielded numerous skeletons in burial position, with associated artifacts.

Unlike the Neandertaloids, the Cro-Magnons were tall and straight, with relatively long legs, straight thigh bones, and the complete double curvature of the spine that permitted the balance of the head as in modern man. The chin was prominent, the jaws not protruding, the forehead high, and the brain fully as large as in modern races. In physical development the Cro-Magnons were essentially modern (Fig. 333).

In mental development, also, they were superior, for they had abundant and well-formed implements. They used bone for awls and ivory for skewers and ornaments, they made spears and bows and arrows, and they dressed themselves in fur. Their bodies they ornamented with sea shells derived from the Mediterranean and Atlantic coasts,

with fossil shells from places far inland, with the teeth of mammals and even of human beings Toward the close of the last ice age they made beads and bracelets and other objects of shell and ivory

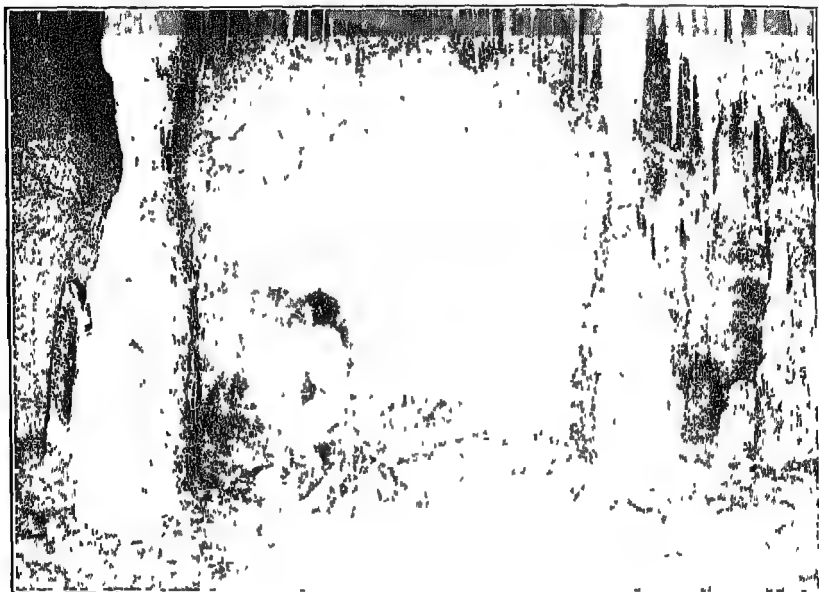
Armed with better weapons than any of their predecessors, and with a fuller knowledge of their use, the Cro-Magnons were able to take better advantage of their environment Thus, they had more

*Chicago Natural History Museum*

FIG 334 The cave of Gargas in southwest France, as restored by Frederick Blaschke, showing a prehistoric artist of the Cro-Magnon race at work on the pictures that ornament the cavern walls Engravings of elephants and bison may be noted

ease and time for reflection, and we witness in them the development of art and culture that excite the wonder and admiration of all anthropologists Besides personal adornment and the use of clothing, this artistic development was expressed in picture writing on the walls of their caves, in sculpture upon fragments of stone or on bone implements, and finally in polychrome paintings like those preserved on the walls of certain caverns in France and Spain (Fig. 334). The carbon ratio in charcoal from Lascaux cave, which bears similar pictures, indicates habitation about 15,500 years ago

The Cro-Magnons were the last of the Paleolithic races in Europe, being replaced by Neolithic peoples Their history falls into four cultural stages, the Aurignacian, the Solutrean, the Magdalenian, and

the Azilian, each characterized by certain types of flint workmanship The race was not exterminated like the older human species, for the Cro-Magnon stock, interbred with late migrants from western Asia, is the direct ancestor of living races of South Europeans

## Neolithic Peoples and the Beginning of Civilization

As the last ice sheet disappeared from Europe, the climate moderated and became moister The reindeer, which had been the chief source of food and clothing for Cro-Magnon man while the ice still occupied northern Europe, now vanished from most of the continent These changes in climate and food were accompanied by human migrations, as man spread northward in the wake of the vanishing ice About this time the art of finishing stone implements by grinding and polishing was developed in southern Europe, and a new culture, the Neolithic, spread quickly over the continent This was accompanied by the development of the art of making pottery, the domestication of animals, and the adoption of habits of communal life Later on, permanent habitations in the form of stone or wooden huts or tents of skins became general, and agriculture was pursued In order to secure protection, villages were commonly built on piles over lake shores, swamps, or streams

With the spread of Neolithic culture, civilization had truly begun, replacing the barbarism and savagery of Paleolithic peoples There is evidence of this change in human affairs as early as 18,000 B C in Asia Minor, Arabia, and Persia Probably the oldest center of Neolithic culture yet known is the ancient city of Susa in Persia, which is said to date from at least 20,000 B C The culture had spread to the island of Crete by 14,000 B C and to Denmark by about 12,000 B C.

## Early Man in North America [3]

All the Paleolithic races of men described above lived in the Old World It is generally accepted that man evolved in that hemisphere, for no remains of the higher primates are known in America The date of man's first migration to this continent is a problem long under discussion, but one on which numerous recent finds have thrown light It now appears certain that he arrived before the extinction of several of the characteristic Pleistocene mammals, notably the Columbian elephant, the American mastodon, a large extinct species of bison, a native camel, three species of horse, and the giant ground-sloth In-

deed, it has been suspected that he may have contributed to the extinction of some of these great game animals All the American human fossils are attributable, nevertheless, to the modern species, *Homo sapiens.*

A notable discovery of human bones was made at Vero, south of Daytona Beach, Florida, in 1916, and at Melbourne, about 40 miles farther south Numerous fragments of human remains occur at the

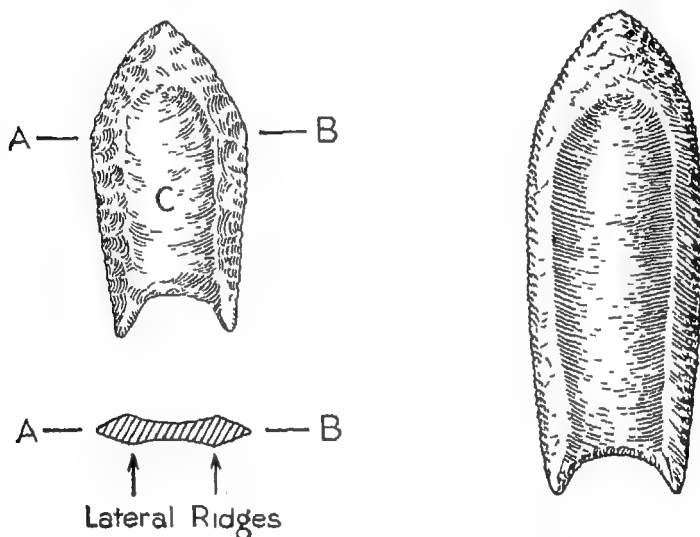



Fig 335 Folsom points from the Lindenmeier ranch in Colorado, after F Roberts The longitudinal fluting (C) of these finely chipped points is distinctive

latter place in a bed of sand that also contains bones of the giant ground-sloth, two extinct species of horse, the mastodon, the Columbian elephant, and a saber-tooth cat

In 1926 crude stone implements were found near Folsom, New Mexico, associated with an extinct species of buffalo, *Bison taylori* Later excavation revealed an arrow point between two bison ribs, and eventually the remains of 40 to 50 specimens of the extinct bison were found within a small area, representing a kill and barbecue Among these were 16 arrow points of a distinctive type of workmanship now known as the *Folsom culture* (Fig 335) In recent years this culture has been found widely distributed in southwestern United States, and in several places it is associated with extinct animals A notable example is the Lindenmeier site north of Fort Collins, Colorado, where, at a depth of 14 or 15 feet below the present surface, the Fol-

som culture is found associated with a "bison kill" similar to that at Folsom. Here the remains of an extinct camel were found with the bison. From this ancient camp site some 2000 stone implements have been recovered, including scrapers, drills, gravers, and blades.

A similar occurrence was found near Plainview, Texas, in 1944,[4] where extensive quarrying in a gravel bed led to the recovery of skeletons of between 50 and 100 bison of an extinct species larger than the modern buffalo. With these were found 19 projectile points and 8 stone scrapers. It is believed that the bison were stampeded into falling from the river bluff. The artifacts resemble those at Folsom. At this quarry the only other animal found was a large wolf, but, near by, the same bed yielded the Columbian elephant and a fossil horse.

Artifacts have also been found deeply buried in river-terrace gravels at numerous localities in southwestern United States, and in several of these they are associated with remains of extinct mammals.

Terraces along Blanco Creek about 100 miles southeast of San Antonio, Texas, for example, have yielded 6 sites in which flint artifacts are associated with bones of extinct animals including elephants, mastodons, horses, bison, camels, glyptodons, etc. Similar deposits at Frederick, Oklahoma, cited in the first printing, should be regarded with skepticism since the artifacts were not seen in place by trained scientists and may not be contemporaneous with the extinct mammals.

The valley about Mexico City has yielded several bits of evidence of early man. A skeleton and associated artifacts were found beneath a lava flow in the suburban village of San Angel, and the same culture was found beneath 10 to 12 feet of sediments northwest of the city. The lava flow is believed to have occurred at least 2000 years ago, and possibly as much as 10,000 years. Hence these people long preceded the Aztecs, who date from about A.D. 500. In 1946 more remains were found near Tepexpan. Here a human skeleton was discovered in a layer that also yielded several artifacts (three gravers, a scraper, and a bone point), as well as bones of the imperial mammoth, bison, horse, and glyptodont.[5]

These are but samples of a large number of occurrences of either artifacts or human fossils associated with the large extinct mammals that were common in North America during the Pleistocene epoch. Such deposits are certainly several thousands of years old, but it is not yet possible to determine whether they are as old as the last glacial age.

In 1931, however, a skeleton was found in varved clays near Pelican Rapids, Minnesota, in circumstances that indicate drowning in a pro-

glacial lake The skeleton is that of a young woman and was found at a depth of 9 feet, 9 inches, in varved clay Workmen who exhumed the skeleton assert that the lamination in the clay extended unbroken over it, so that it could not be ascribed to later burial

It is quite clear, in short, that man arrived in North America several thousands of years ago, probably during the recession of the last ice sheet

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[1] *A Review of the Stratigraphy of Java and Its Relations to Early Man,* by G H R von Koenigswald In *Early Man,* edited by G G MacCurdy J B Lippincott Co, Philadelphia, 1937

[2] See papers by Davidson Black and others in Bulletin of the Geological Society of China, Vol 10, 1931, pp 165–178, Vol 11, 1931, pp 107–139, 147–154 Also see *Man or Ape?*, by Franz Weidenreich Natural History, Vol 45, 1940, pp 32–37

[3] *Early Man in America,* by E H Sellards Bulletin of the Geological Society of America, Vol 58, 1947, pp 955–978

Gives a brief summary and a bibliography of all recognized occurrences

[4] *Fossil Bison and Associated Artifacts from Plainview, Texas,* by E H Sellards, Glen L Davis, and G E Mead Bulletin of the Geological Society of America, Vol 58, 1947, pp 927–954

[5] *Tepexpan Man,* by Franz Weidenreich Science, Vol 105, 1947, pp 493–494

## Collateral Reading

*The Coming of Man,* by George G MacCurdy 157 pages The University Society, New York, 1932

A brief, authoritative survey of the field of prehistoric anthropology

*Concerning Man's Origin,* by Sir Arthur Keith 188 pages G P Putnam's Sons, New York and London, 1928

*The Evolution of Man,* by G Elliot Smith 159 pages Oxford University Press, 1924

*Developments in the problem of the North American Paleo-Indian,* by Frank H H Roberts, Jr Smithsonian Misc Coll, Vol 100, 1940, pp 51–116

# VI. EPILOGUE

"It is always necessary to close a lecture on Geology in humility On the ship *Earth* which bears us into immensity toward an end which God alone knows, we are steerage passengers We are emigrants who know only their own misfortune The least ignorant among us, the most daring, the most restless, ask ourselves questions, we demand when the voyage of humanity began, how long it will last, how the ship goes, why do its decks and hull vibrate, why do sounds sometimes come up from the hold and go out by the hatchway, we ask what secrets do the depths of the strange vessel conceal and we suffer from never knowing the secrets

"You and I are of the group of restless and daring ones who would like to know and who are never satisfied with any response We hold ourselves together on the prow of the ship, attentive to all the indications that come from the mysterious interior, or the monotonous sea, or the still more monotonous sky We console each other by speaking of the shore toward which we devoutly believe we sail, where we shall indeed arrive, where we shall go ashore tomorrow, perhaps This shore not one of us has ever seen, but all would recognize it without hesitation were it to appear on the horizon For it is the shore of the country of our dreams, where the air is so pure there is no death, the country of all our desires, and its name is 'truth' "

—Pierre Termier

## Appendix A

# AN INTRODUCTION TO ANIMALS AND PLANTS

**Scientific Names.** The beginner in natural history is usually dismayed by the scientific names of unfamiliar types of animals and plants, and is inclined to wonder why common names are not used instead. The answer to this is very simple: a name is common only because it is familiar. Such words as *boa constrictor*, *gila monster*, and *rhinoceros* are common, but a small child finds them fully as difficult as *Homo sapiens* (man), or *Equus caballus* (the horse). Moreover, only a few thousand kinds of animals are at all commonly known, and the rest, already exceeding 825,000 kinds, can therefore have no really "common" names.

Furthermore, so long as we have a diversity of languages, there can be no really common names of general and world-wide usage. To the Germans, the common name of the horse is *Pferd*, to the French, *cheval*, to the Italians, *cavallo*, etc. Moreover, a common name such as *bear* has many different meanings, to a New Englander it implies one species, to a Montanan another, and to an Alaskan a quite different kind of bear. Therefore, if naturalists of all countries are to share in scientific studies, it is obviously necessary that each species should bear a name that applies to one kind alone and is recognized in all languages. For such names, naturalists have wisely turned to the classical languages, Greek and Latin.

The early naturalists did, indeed, give each kind of animal but a single name. Thus, in the Roman Empire the cat bore the name *felis*, and the horse was called *equus*. This scheme sufficed so long as only a few hundred kinds of animals were known, and the scholars of the civilized world all lived in a relatively small area about the Mediterranean. But as culture spread during the Middle Ages, and animals from other regions were studied, it became necessary to accompany each name with a short diagnosis or description in order to distinguish it from some similar, previously known kind. Latin scholars at first used the name *felis* for the domestic cat, but they later became acquainted with the great tawny cat of Africa, as well as the spotted cat of the tropics.

When it became necessary to accompany the common name with sufficient adjectives or descriptive phrases to indicate clearly which kind was meant, the great Swedish naturalist, Linnæus, devised the plan of giving each species a double name, the first representing the group (genus), the second a special or specific name for that particular kind The latter is generally a descriptive or qualifying adjective standing in place of a descriptive paragraph, and, in harmony with the Latin custom, it follows the word which it modifies Thus, the house cat became *Felis domestica,* and the great spotted cat, *Felis leopardalis* (Lat *pardalis,* spotted) The scientific name is, therefore, in reality a nickname, or an abbreviation of the longer diagnosis that would otherwise be required

It should be noted that the generic name is capitalized, and that the specific name is not

**Classification of Animals and Plants.** In dealing with any large or complex group of objects, some scheme of classification or orderly grouping is required To appreciate this fact, we need only contemplate an army of individuals without organization, a great library with the books placed at random on the shelves, or a dictionary with the words arranged by chance! Nowhere is the need for organization more keenly felt than in the study of the enormously varied forms of animal and plant life Here, obviously, the most useful basis of classification is blood kinship, and a *biologic classification* has therefore been adopted which aims to group creatures according to their degree of actual relationship, regardless of superficial resemblances or differences

In this biologic scheme, the animal and plant kingdoms are divided, first, into *phyla* (Gr *phylon,* stock or race), each phylum including organisms that are alike in some fundamental anatomical characters For example, animals with backbones form the phylum *Vertebrata* (Lat *vertebratus,* having a backbone), those with jointed legs and bodies, such as insects, spiders, and crabs, form the phylum *Arthropoda* (Gr *arthron,* joint, + *pous,* foot)

Each phylum in turn is divisible into *classes,* within which the resemblances are still closer For example, among the vertebrates the fishes constitute one class, birds another, and mammals a third Classes are further subdivided into *orders* Thus, the class Mammalia includes the orders *Carnivora* (flesh-eating types), *Rodentia* (gnawers like rats and squirrels), etc Orders are divisible into *families,* and these in turn into *genera,* each genus including one or several kinds (*species*) of animals that are very closely related and struc-

turally alike For example, the cats form the genus *Felis*, and the dogs and wolves the genus *Canis* The species is the next smallest unit, including individuals very closely alike

## Animals

The following table presents in simple form the major subdivisions of the animal kingdom, groups that are wholly extinct being italicized See also the *Tree of Life*, Fig 32, p 57

### A Simple Classification of the Animal Kingdom

Phylum **Protozoa**—single-celled, generally microscopic animals Ex amœba, foraminifera, radiolaria, and many disease germs
Phylum **Porifera**—sponges
Phylum **Cœlenterata**—coral-like animals, lacking viscera
  Class **Hydrozoa**—hydroids, *graptolites*
  Class **Anthozoa**—corals and sea-anemones, *tetracorals*, hexacorals, *honeycomb corals*
Phylum **Platyhelminthes**—flatworms (never fossil)
Phylum **Nemathelminthes**—threadworms (never fossil)
Phylum **Trochelminthes**—rotifers, all microscopic (never fossil)
Phylum **Brachiopoda**—brachiopods
Phylum **Bryozoa**—moss animals
Phylum **Echinodermata**—echinoderms
  Class **Asteroidea**—starfish
  Class **Echinoidea**—sea-urchins, heart-urchins, sand dollars
  Class **Crinoidea**—sea-lilies or feather-stars
  Class **Blastoidea**—*sea buds* or *blastoids*
  Class **Cystoidea**—*cystoids*
Phylum **Mollusca**—molluscs
  Class **Pelecypoda**—clams, oysters, scallops
  Class **Gastropoda**—snails, conchs, etc
  Class **Cephalopoda**—squids, devilfish, nautiloids, *ammonites*, and *belemnites*
Phylum **Annelida**—segmented worms, earthworms, beach worms, etc
Phylum **Arthropoda**—invertebrate animals with jointed legs.
  Class **Crustacea**—lobsters, crabs
  Class **Myriapoda**—centipedes, millipeds, etc
  Class **Arachnoidea**—spiders, scorpions, *eurypterids*, *trilobites*
  Class **Insecta**—insects
Phylum **Vertebrata** (Chordata)—animals with backbones
  Class **Pisces**—fishes (actually four classes)
  Class **Amphibia**—salamanders, frogs, *labyrinthodonts*
  Class **Reptilia**—crocodiles, turtles, *dinosaurs*, *ichthyosaurs*, *plesiosaurs*, *mosasaurs*, *pterosaurs*, snakes
  Class **Aves**—birds
  Class **Mammalia**—milk-feeding, warm-blooded animals (including man)

### *Phylum Protozoa*

Single-celled animals constitute the phylum *Protozoa* (Gr *protos*, first, + *zoon*, animal), so called on the assumption that it includes the most primitive types of animal life Although widely distributed and extremely numerous, protozoans are nearly all microscopic and therefore are seldom seen

Each protozoan is a tiny droplet of fluid living matter enclosed in a membranous cell wall Unlike higher animals, it has no special visceral organs for digestion, circulation, reproduction, etc Food consists of other microscopic creatures, commonly plants, which are swallowed whole Lacking a mouth, the little animal takes its food through a temporary rupture in its cell wall, and later voids the indigestible residue by the same means Once in the body, the food particle is attacked by fluids that digest it, and the single-celled animal assimilates this food without the need of a circulatory system When fully grown, the tiny animal reproduces by simply splitting into two or more young, each of which is like the parent but smaller Since the parent passes completely into its offspring, *there is no death* in the normal course of events for these simple creatures Individuals may be killed, of course, by unfavorable environment or by other animals, this, however, may be considered accidental, for death is not the inevitable fate of each individual, as it is with all higher animals

Although protozoans probably exceed all other types of animal life combined, both in number of individuals and in total bulk, the vast majority are soft-tissued and incapable of fossilization There are, however, two prolific groups of them that form delicate shells of calcium carbonate or silica, and have left an imposing record These are the orders Foraminifera and Radiolaria

The *Foraminifera* (Fig 336) build tiny chambered shells, commonly of calcium carbonate They inhabit all the oceans but are rarely found in fresh waters The majority live on the bottom or cling to seaweeds, but about twenty kinds float near the surface of the open oceans, whence their shells, abandoned at time of reproduction, rain down like a snowfall to cover the sea floor The commonest of these is *Globigerina,* and the soft, fine-grained, limy deposit made mainly by its shells is known as *globigerina ooze* (Fig 336) Approximately 50,000,000 square miles of the sea floor are now covered to an unknown depth by these deposits At various times in the geologic past, foraminiferal shells have accumulated in shallow water to form extensive beds of chalk or limestone The pyramids of Gizeh, for example, are

made of a limestone that is widely spread in the Mediterranean region and is largely made of coin-shaped shells known as *nummulites* (Fig. 321, p. 494). Still older limestones of the late Paleozoic are formed of *fusulines*, a tribe having shells about the size and shape of wheat grains (Fig. 173, p. 277).

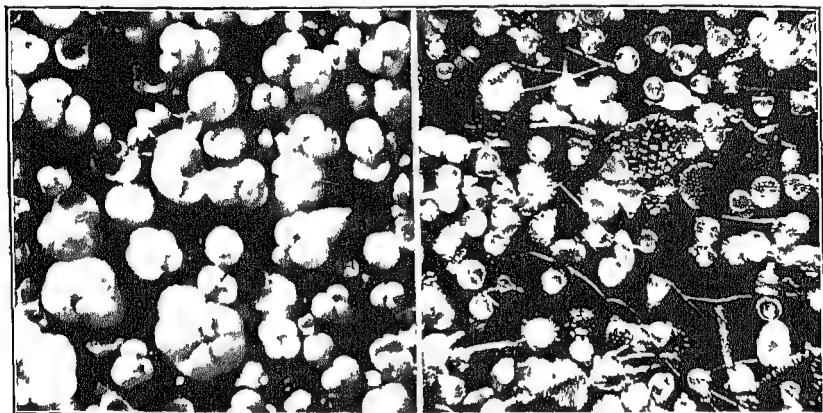
The *Radiolaria* (Fig. 336) make their shells of silica. Differing from the capsule-like shell of the foraminifer, these are of a loose,

*Yale Peabody Museum*

Fig. 336. Protozoan shells. Left, globigerina ooze (×10) dredged from a depth of 2898 feet about 100 miles west of Martinique, West Indies. Right, radiolarian ooze (×35) from the Miocene beds of the island of Barbados, West Indies.

open texture, like a delicate glass sieve. They form deposits of radiolarian ooze on parts of the deep sea floor.

### *Phylum Porifera*

The Porifera or sponges are multicellular animals in which there is little specialization of tissues. The "bath sponge" is but the silken skeleton of one highly specialized type. The essential features of the group are better displayed by a very simple sponge (Fig. 337*A*). Such an individual has the form of a slender vase; there is nothing to it but a living *wall* surrounding a large hollow space. This wall is made up of three layers like a jelly sandwich, the outer layer being formed of protective cells (ectoderm), the inner layer of feeding cells (endoderm), and the middle layer of a noncellular jelly-like substance (mesoglea). The endodermal cells feed as do protozoans, each capturing and swallowing other microscopic organisms; the ectodermal cells do not take food but absorb what is needed from the near-by endo-

dermal cells Thus no digestive or circulatory organs are required To strengthen this delicate wall, either mineral spicules or thread-like fibers of spongin, an organic substance allied to silk, are formed in the gelatinous layer These are secreted by specialized cells and are united to form a loose meshwork In the bath sponge the spicules are all made of spongin, but in many sponges the spicules are of silica or calcium carbonate (Fig 337*C*) The mineral spicules are com-

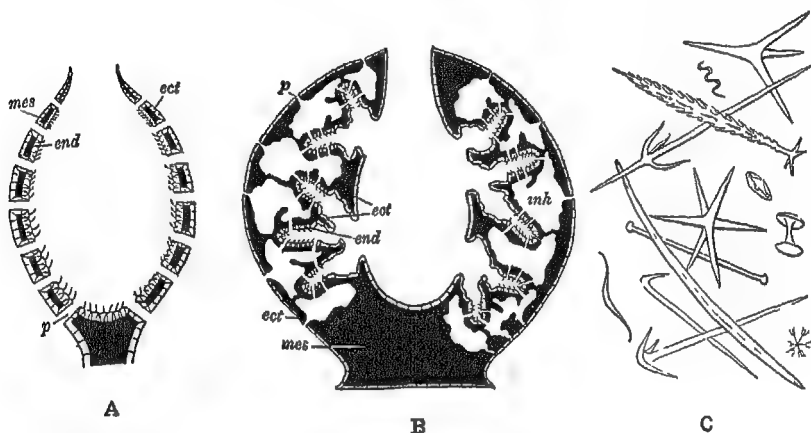



Fig 337 Sponges *A*, diagrammatic vertical section of a very simple sponge, *B*, similar section of a more complex sponge, *C*, various types of sponge spicules, greatly enlarged *ect*, ectoderm, *inh*, inhalant canal, *mes*, mesoglea, *p*, wall pore From Brooklyn Museum of Natural History

monly preserved, and some of these, found in the Pre-Cambrian rocks of the Grand Canyon, are among the oldest records of life on the Earth

## *Phylum Cœlenterata*

The third phylum of animals includes the *hydroids, corals,* and *jellyfish* These, like the sponge, consist essentially of a body wall, lacking any internal organs, whence the name Cœlenterata (Gr *koilos,* hollow, + *enteron,* inside cavity)

**Hydroids.** *Hydra* is a simple representative of the phylum, and particularly of the class *Hydrozoa* A vertical section through its slender subcylindrical body (Fig 338) shows a wall of three layers, as in the sponge But in three respects it is vastly ahead of the sponge First, it has muscular tissue that permits change of shape and even locomotion, and makes possible a circlet of muscular tentacles about the mouth with which to capture food, second, in the inner

layer are special gland cells that excrete digestive juices into the central cavity, and, third, it bears stinging cells like those of the jellyfish that can paralyze other animals coming into contact with it The hydroid is thus able to capture, swallow, and digest animals almost as large as itself (Fig 338)

Hydras live as solitary individuals, but many hydroids reproduce by budding and thus form colonies of individuals organically united (Fig 338). Many of these secrete a bell-like or vaselike sheath (hydrotheca) about their body as a protection These sheaths are formed of chitin, a substance similar to finger nails

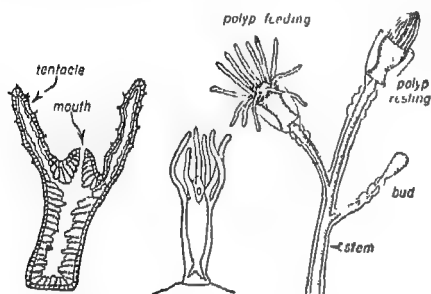



Fig 338 Hydroids Left, diagrammatic vertical section of *Hydra*, much enlarged, center, *Hydra* devouring a young trout (×2), right, a colonial hydroid, *Obelia*, with two adult individuals and a young bud

The *graptolites*, commonly considered an order of hydroids,* lived in early Paleozoic time, forming slender colonies in which individuals were closely ranked along a common axis They are generally preserved in dark shales where they are pressed flat and reduced to a film of carbon superficially resembling heavy pencil marks on the stone, whence their name (Gr *graptos*, written, + *lithos*, stone) (Fig 95, p 163)

**Corals.** The corals and sea-anemones form another class of this phylum, the *Anthozoa* (Gr *anthos*, flower, + *zoon*, animal), so named because of their bright colors and flower-like symmetry (Fig 339) The coral animal resembles *Hydra* in essentials, but with the addition of thin radial partitions (mesenteries) that extend from the wall part way into the central cavity, subdividing it into a series of alcoves

The coral animal secretes about its side and base an external skeleton of calcium carbonate The animal is correctly termed a *polyp*, and its skeleton, *coral*

For some unknown reason the base of the coral polyp is invariably marked by radial infoldings which alternate in position with the internal mesenteries The skeleton secreted against this base is marked by radial ridges or plates known as *septa* Coral polyps may

* Kozlowski has advanced arguments for placing the graptolites with the hemichordates, lowly relatives of the vertebrates

live singly, but many kinds reproduce by budding new polyps from the margins of the older and thus develop colonies in which many individuals co-operate to build a complex stony skeleton

The skeleton of a solitary coral may be cushion-shaped or horn-shaped or subcylindrical, and usually has a cuplike depression at the summit in which the base of the polyp is housed In colonial forms the skeleton is commonly branching or massive, with depressions for the bases of the individual polyps *The radiating septa are absolutely distinctive of the coral skeleton and serve to distinguish it from all other types of shells*

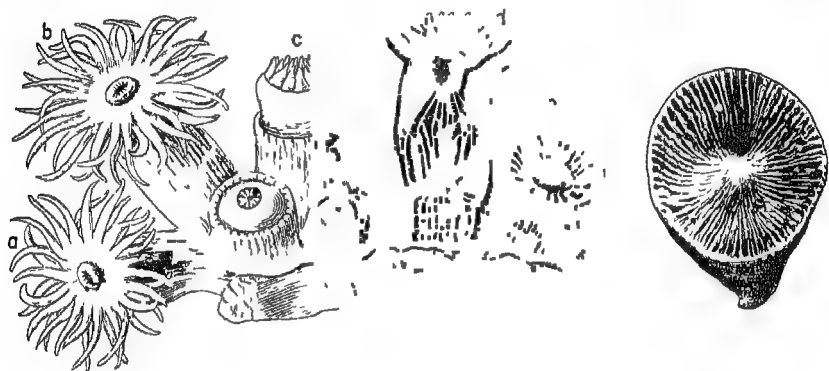



Fig 339 Left, portion of a colony of a modern coral with living polyps (*a–d*) and an exposed coral showing the septa (*c*), right, a horn coral

It is well known that corals make reefs in the sea, but only where it is warm and shallow Accordingly, the coral reefs in the rocks of past geologic ages are regarded as evidence of mild temperature and of shallow water Corals have been important agents in rock formation at various times in the past Coral reefs now occupy an area of about half a million square miles of the shallow seas, and their limy debris spreads over a vastly greater area

Nearly all the modern corals belong to the subclass *Hexacoralla,* so named because their septa are introduced in cycles of six or multiples of six In these the septa are equally spaced, so that they seem to radiate with regular symmetry in all directions from the center This group has been the dominant one since the beginning of Mesozoic time The subclass *Tetracoralla* (Fig 339, right), on the contrary, which was dominant in the Paleozoic era, shows more or less conspicuous bilateral symmetry, with septa introduced in cycles of four

*Phylum Brachiopoda*

The brachiopods constitute a phylum of rather small marine animals that invariably bear an external shell of two pieces, known as valves (Fig 340) Although between 200 and 300 kinds are now living, they are seldom seen on the beach and are hardly known except to specialists, but they are extremely abundant fossils, especially in Paleozoic rocks, and so challenge the interest of geologists

The body is much more complex than that of the coral, having a digestive system, kidneys, a nervous system, reproductive organs, and

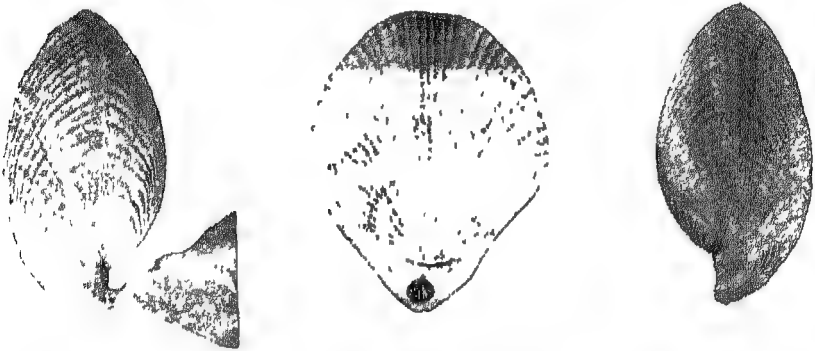



FIG 340 Brachiopods Left, a shell in position of growth, attached to a point of rock by the pedicle Center, dorsal view of same, showing the pedicle foramen and the bilateral symmetry (i e , each side is a mirror reflection of the other) Right, side view showing that the valves are unequal in size and in shape

well-developed muscles. In life, the animal is attached to the bottom by a fleshy stalk (pedicle) at the posterior end, its mouth facing upward The two valves of the shell are hinged together at the posterior end of the body and can be opened more or less widely at the front They are borne on the back and front surfaces of the body (not on the sides), and thus a plane of symmetry passes through the middle of each valve Special muscles open and close the shell, and a pair of interlocking teeth and sockets at the posterior end forms a hinge A hole (pedicle foramen) for the passage of the stalk is usually present near the apex of the ventral valve

In so far as the brachiopod shell consists of two valves, it resembles the shell of a clam, but the likeness is purely superficial The structure of the body is unlike that of a clam, and the shell valves are borne in a wholly different position In the clam, the valves are on the *sides* of the body and are hinged *along the back*, in the brachiopod, they are borne on the *back* and *front* surfaces and are hinged *across the pos-*

*terior end.* As a result, the symmetry of the shell is quite dissimilar in these two groups, the brachiopod shell being *inequivalved* although each valve is *equilateral,* each half being a mirror reflection of the other, like the left and right sides of a coat. The clam shell is *equivalved,* right and left valves being mirror reflections of one another (except in deformed types like the oyster), but each valve is *inequilateral,* the front and hind ends being normally different in shape.

Brachiopod shells vary greatly in shape (Pl. 4, figs. 10–22), some being strongly biconvex, others plano-convex, and others concavo-convex, the space between the valves in the last type being so thin that the animal must have had the proportions of a flatworm. In many brachiopods the hinge is short, and the posterior end of the shell pointed or "beaked" as in Fig. 340; in others, it is long and straight, and the shell is "square-shouldered." Some shells are smooth, many are ribbed, and some are spiny. In spite of the diversity of form, *the brachiopod shell is easily recognized by its symmetry.*

Brachiopods are rather small animals, the average length of shell being between 1 and 2 inches. A few attained a diameter of 3 or 4 inches, and the largest that ever lived had a breadth of about 1 foot.

### *Phylum Bryozoa*

The Bryozoa or moss animals form another important phylum little known to the general public, in spite of the fact that living forms are commonly attached to the rocks and seaweeds everywhere along the seacoast (Fig. 341). Anatomically the bryozoan is very simple and in many respects more like a brachiopod than other animals, but, unlike the brachiopod, it is invariably minute and always grows in colonies. The individuals rarely attain a diameter much greater than that of a period on this page, but thousands of them living together may form a colony some inches across. Locally they combine to make reef limestones (Fig. 118, p. 192).

Unlike the brachiopod, the bryozoan forms a simple skeleton in the form of a slender tube or a boxlike cell, with an opening at or near one end through which the front end of the body can be thrust out while feeding. Many bryozoans have only a soft, delicate covering of chitin, but the majority secrete a skeleton of calcium carbonate.

The form of the colonial skeleton varies enormously with different species. It may be branching and mosslike, whence the name (Gr. *bryon,* moss), or stemlike, leaflike, massive, or encrusting. In spite of all this diversity, the bryozoan skeleton is easily recognized because it is made up of minute tubules or cells.

## *Phylum Echinodermata*

The *echinoderms* are peculiarly different from all other animals. This great phylum includes the starfishes, echinoids, crinoids, blastoids, and cystoids. Their bodies are short and commonly globular. Almost all have a radial and five-rayed symmetry. Nearly all develop a shell in the form of limy plates that are secreted in the body

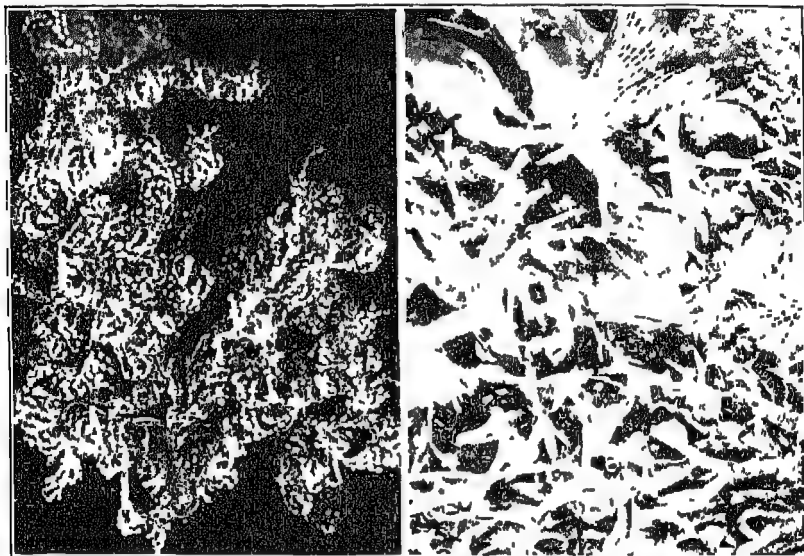



Fig. 341. Bryozoa. Left, *Menipea*, a living colony of mosslike form. Right, fossil bryozoans of many kinds weathering from a piece of Lower Devonian limestone. Natural size.

wall and fit edge to edge like the pieces in a mosaic. The types enumerated above represent five distinct classes which will be discussed in order.

**Echinoids or Sea-urchins.** A typical echinoid (Fig. 342) has a globular or bun-shaped body bristling with slender, movable spines, whence the name (Gr. *echinos,* hedgehog). The mouth is at the center of the lower side, and the axis of the body is vertical. Stripping away the spines, we find the body wall of the animal to be a rigid, boxlike shell of polygonal plates arranged in twenty vertical columns. Upon these plates are scattered small rounded nubs, each of which was the pivot for a spine.

Radiating from the summit of the shell to the mouth are five paths along which the plates are thickly perforated with small double-

barreled pores These paths are the food grooves or *ambulacral areas* In life each pair of pores bears a slender muscular organ known as a *tube-foot* The tube-feet are part of a remarkable "*ambulacral sys-*

Fig 342 Three views of the echinoid, *Cidaris* Left, a young individual as it appears alive, center, upper surface of shell with spines removed, showing the five ambulacral areas (with rows of pores) and five interambulacral areas (with large bosses for spine bases), right, side view showing the arrangement of the plates to be in vertical columns About ½ natural size

*tem*," found only among the echinoderms, which serves for feeble locomotion, for the gathering of food, and for respiration The body cavity is spacious and includes a well-developed digestive system, a nervous system, and reproductive organs

We have described a typical sea-urchin as a radially symmetrical animal, but there are some specialized types (heart-urchins and sand dollars) in which a secondary bilateral symmetry has modified the primitive, pentameral form In all echinoids, however, a five-rayed symmetry is clearly evident even though somewhat irregular

*Yale Peabody Museum*

Fig 343 A primitive starfish, *Devonaster eucharis* Artificial cast from a natural mold in Middle Devonian sandstone of New York Natural size

**Starfishes.** Next of kin to the echinoids, the starfishes are distinguished by their star-shaped form (Fig 343), the body being depressed and extended at the sides into tapering rays The skeleton is made of small limy plates, articulated by fleshy tissues so as to permit some flexibility as in a coat of chain-mail

Starfishes probably have been abundant since early Paleozoic time, but are rarely found as fossils, because their loosely joined plates fall

apart with the decay of the flesh, and such small irregular plates are not easily recognized

**Crinoids** The crinoids or sea lilies (Fig 344) look more plant-like than animal-like, for their globular bodies are supported by flexible stalks which anchor them to the sea floor, mouth upward The animal consists of three chief parts, a *stem,* the *body* proper, and a series of branching *arms*

In spite of its plantlike appearance, the crinoid is an animal, essentially comparable in its structure to a starfish, though in making this comparison we must turn the starfish with its mouth upward

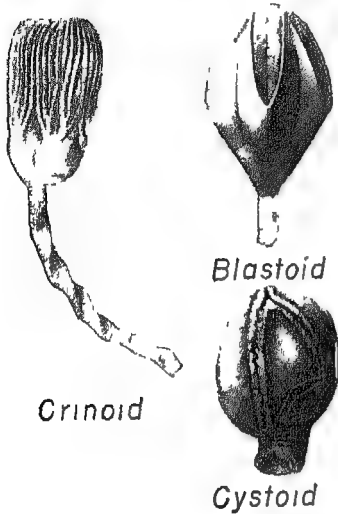



Fig 344 Stalked echinoderms A crinoid, *Platycrinus*, with part of its stem, a blastoid, *Pentremites*, without its stem, a cystoid, *Sphærocystites*, with most of its stem missing Natural size After Wachsmuth and Springer, Romer, and Schuchert

The body of the crinoid is covered by a series of limy plates which fit edge to edge like those of the echinoid These plates are arranged in several horizontal cycles, one above another, beginning at the upper end of the stem Normally the plates in each cycle number five or some multiple of five, so that five-rayed symmetry is the rule here, as in the sea-urchins and starfish The stalk is strengthened by the secretion within it of a series of button-shaped limy plates which are superposed like buttons on a string These "stem joints" are united by muscular tissue, so that the stem has flexibility enough to let the animal swing with the currents The mouth is at the summit of the body, and from it the food grooves radiate on to the upper sides of the arms Indeed, the arms are structures developed merely to extend the food grooves

The living crinoids are brilliantly and beautifully colored with shades of lavender, purple, red, lemon-yellow, or brown, and it is fitting that they should be called sea lilies They tend to grow in patches on the sea floor and where present are commonly very abundant, so that they present much the appearance of submarine flower beds as they sway gracefully with the bottom currents Upon the death of the animal its limy plates commonly fall apart Crinoid remains are

among the commonest fossils in some of the Paleozoic formations, and they give distinctive character to "crinoidal limestones," some of which have wide extent.

**Blastoids.** The blastoids or sea buds (Gr. *blastos,* bud) form another group of stalked echinoderms (Fig. 344). Their bodies are globular or bud-shaped and are encased in a shell of 13 chief plates of which 3 form a basal cycle, while 2 succeeding cycles have 5 plates each. There are no arms, the food grooves lying upon the surface of the body as they do in the echinoids. These food grooves are always simple, 5 in number, and arranged in perfect five-rayed symmetry about the mouth, which is at the summit. The 5 ambulacral areas are submerged a little below the level of the chief body plates in such a fashion as to give the entire body a superficial resemblance to a flower bud in which the sepals are just beginning to part.

Blastoids are all extinct and are known only from Paleozoic rocks. They were very abundant during only one geologic period, namely, the Mississippian.

**Cystoids.** The cystoids (Gr. *cystis,* bladder) are primitive echinoderms with globular or almond-shaped bodies but differ from both crinoids and blastoids in that their plates are irregularly arranged, so that the body shows no definite symmetry (Fig. 344). They are extremely varied in details. Some had arms, and others had none; many were stalked, but some apparently were attached directly to the sea floor or were free. They were the most primitive echinoderms.

### *Phylum Mollusca*

This great phylum includes the clams, the snails, the devilfish, the squids, the pearly nautilus, and the extinct ammonites. These commonly possess solid, limy, external shells, and they are generally known as "shellfish." The phylum is an enormous one, with probably no fewer than 50,000 species now living.

**Pelecypods (Clams).** A typical clam has a laterally compressed body encased in a bivalved shell, the two halves of which *lie on the sides of the body and are hinged along its back.*

The body is generally elongated, and the mouth is at the front end, but there is no distinctly marked head. Lining each valve there is a thin, fleshy extension of the body wall, the *mantle,* which hangs freely about the body like a loose garment. The most conspicuous organs are the great gills, which hang as a double pair of thin plates between the mantle and the sides of the body.

The shell (Fig 345) is opened by an elastic ligament at the hinge-line, which is placed under tension (or in some cases under compression) when the valves are closed The shell of most clams is closed by a pair of heavy transverse muscles which run through the animal's body from side to side Normally one muscle is near the front, and the other near the back end

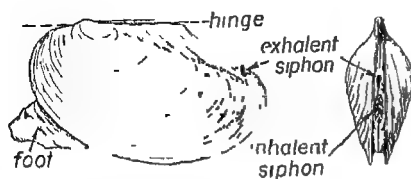



Fig 345 Pelecypod shell The common river clam, *Anodonta*, seen from the left side and from the posterior end

The typical clam is free to creep slowly about by thrusting out the ventral edge of its muscular body wall, which serves to draw the animal along Secondarily, many clams have given up this freedom and lie on one side and adhere to the bottom, as does the oyster, or attach themselves to the rocks by silken threads, as does the blue clam Still others burrow in the mud or even in hard rock.

The clam shell, like that of all other molluscs, consists of three layers The outer one is a film of organic material to protect the limy part of the shell from solution The second layer is of calcite and commonly has a white, porcelain-like appearance, while the inner layer is made of aragonite or mother-of-pearl and has the iridescence of pearl In fact, the precious pearl is a secretion formed between the mantle and the shell, usually in an attempt by the animal to protect itself against a parasite or other irritant

Fig 346 Gastropods Upper right, empty shell with front side of spire cut away, upper left, another shell with the snail crawling upward on the page, the head, with eyes and tentacles, showing above the shell, below, a common land snail in crawling position with creeping "foot" extended and shell coiled over the back After Hatschek and Cori

**Gastropods (Snails).** Though fundamentally like the clam in many of its anatomical structures, the snail is in several ways more highly specialized It has an elongate

muscular body with a distinct head bearing a pair of eyes and a pair of tentacles or feelers Its mouth is provided with a flexible rasping tongue whereby it can shred either plant or animal food, it is therefore not dependent on microscopic objects As a result its gills are small and plumelike, since they are used only for respiration Internal organs resemble those of the clam in most respects

*The shell of the snail is coiled spirally and consists of a single valve* As in the clam, the shell is secreted by a mantle, so that the body may be measurably free

When disturbed, the snail can withdraw completely into its shell, but normally it extends most of its body and creeps about, carrying the shell upon its back (Fig 346) The ventral surface of the body has developed into a muscular creeping sole, whence the group is known technically as the *Gastropoda* (Gr *gaster*, stomach, + *pous*, foot)

Fig 347 Cephalopods The pearly nautilus in its shell The lower shell is intact, but the upper one has the left side cut away to reveal the hollow chambers separated by curved septa and connected by the tubular siphuncle

Most commonly the gastropod shell is coiled in a helicoid (corkscrew-like) spiral, but many fossil forms are bilaterally symmetrical like a watch spring Rapidly expanding shells have few volutions, but slowly expanding ones commonly have high slender spires The shell may be ornamented with spines, ribs, or nodes

**Cephalopods** The squids and devilfish represent a class of molluscs that has been abundant and important in all the seas since early Paleozoic time Unlike the sluggish snails and clams, they are active, alert, and aggressive With their keen eyesight and strong powers of swimming, they alone of all invertebrates are able to compete actively with the vertebrate animals of the seas The living *giant squid* is the largest invertebrate animal of all time

The name cephalopod (Gr *cephale*, head, + *pous*, limb or foot) was suggested by the fact that all members of the class bear a circlet of fleshy limbs about the mouth, which is at the front of the head

The squid and devilfish are shell-less, but the pearly nautilus (Fig. 347) bears an external chambered shell, as did a host of forms known only as fossils. Here, then, are living examples of the two great subclasses of cephalopods. The first is represented by the squids, whose only shell is vestigial and internal, the second by the nautilus with its external, chambered shell. Obviously the shelled cephalopods are of chief interest to the geologist, since they alone are ordinarily preserved as fossils.

The cephalopod shell has essentially the form of a slender cone, which may be straight or coiled (Fig. 106, p. 177). If coiled, it is almost invariably in a flat spiral like a watch spring. The animal's body occupies only the larger end of the shell, the rest having been partitioned off into a series of chambers by transverse plates known as septa. In the living nautilus (and presumably in extinct types) the chambers are filled with gas and thus serve to buoy up the animal and its shell.

The chambers represent successive portions of the shell that were vacated as the growing body moved forward, and the partitions or *septa* are walls secreted against the bluntly rounded posterior end of the body to give it support after the animal has moved forward. These partitions are attached to the inner surface of the shell, and the line of junction is known as a *suture*. The form of the sutures and the course which they take in the shell are of great importance in the classification of the cephalopods. Since the septa are formed within the shell, the *suture is not visible externally, but in fossil forms where the chambers have been solidly filled with mineral matter and the outer shell then dissolved away, the sutures show clearly as sharp lines on the fossil* (Fig. 106). The animal retains connection with the abandoned chambers by a slender tube, the *siphuncle,* which runs back through all the septa. *Septa and a siphuncle are absolutely distinctive features of the cephalopod shell* and serve to distinguish it readily from that of the snail.

Nearly all the primitive cephalopods had straight shells (Fig. 104, p. 174), which, to an animal swimming backward, presented obvious disadvantages. Curved, loosely coiled, and tightly coiled shells were developed in order, and the forms with straight ones eventually became extinct. Besides being compact, the coiled shell brings the supporting gas chambers directly above the center of gravity, so that the animal can float at ease in the water.

*Nautiloids.* The shelled cephalopods are further divisible into two great orders. In the first the septa were simple, saucer-shaped plates

secreted against the smoothly rounded posterior end of the animal's body In these, of course, the sutures run directly around the shell as simple lines without marked flexures (Fig 106), as in the nautilus (Fig 347) This order has been named, accordingly, the *Nautiloidea* The pearly nautilus is their only living representative

*Ammonites* The ammonites, cousins of the nautiloids, also bore chambered shells, but in these the septa were fluted or ruffled near their edges, and as a result the sutures form strongly crenate lines around the shell In the earliest ammonites the fluting of the septa was very slight, and each suture showed only a few simple bends (Pl 8, figs 9, 12), but gradually the fluting became highly complex, and the suture lines accordingly assumed a complicated form (Pl 14, fig 11)

*Belemnites* The belemnites (Fig 228, p 357) were squidlike cephalopods that lived only during the Mesozoic They possessed a conical chambered shell like that of a primitive straight-shelled nautiloid, but it was internal, having been overgrown completely by flesh (Pl 14, fig 8)

Squids are closely related to the belemnites, but in the former the shell (also internal) is reduced to a mere vestige (the "pen")

### *Phylum Arthropoda*

The insects represent a phylum of animals characterized by jointed walking legs, whence the name *Arthropoda* (Gr *arthron,* joint) Other examples are the spiders, scorpions, lobsters, and crabs, and some important fossil groups such as the trilobites and eurypterids All these have segmented bodies and jointed limbs Their bodies are protected by a neatly fitting jointed armor made of chitin In some, like the lobster and crab, this skeleton is strengthened by the addition of calcium carbonate This is undoubtedly the largest and most diversified phylum in the animal kingdom

**Insecta.** The insect possesses an elongate, bilaterally symmetrical body distinctly divided into head, thorax, and abdomen The sharp constriction separating thorax and abdomen, as in the wasp, has suggested the group name (Lat *insectus,* cut into) The abdomen is without limbs, but the thorax bears three pairs of walking legs and commonly two pairs (in one order, one pair) of wings The head bears a pair of compound eyes and a pair of slender feelers or antennæ The mouth is provided with specialized biting or sucking devices The physical senses are rather highly developed

Insects are too easily destroyed to be commonly preserved as fossils, but locally they are found as far back as the late Paleozoic (Fig 192, p 302)

**Crustacea** The lobster and crab represent another great class of the arthropods, but, unlike the insects, these, and nearly all their kin, live in the water and breathe by means of gills The name *Crustacea* (Lat *crusta*, crust) refers to their hard, crustlike armor, but it must be confessed that many examples of the class do not have a hard shell

In most Crustacea each of the segments of both thorax and abdomen bears a pair of jointed appendages (in some forms, part or all of the abdominal segments lack appendages) Commonly those on the thorax are walking legs (as in the lobster), and those on the abdomen are for swimming, but in many of the primitive Crustacea all the limbs are flattened swimming paddles The gills are generally plumose and are attached to the legs

**Arachnoidea.** Spiders and scorpions belong to a class of arthropods known as the Arachnoidea (Gr *arachnes*, spider) The head of a spider is fused to the thorax to form a cephalothorax, which is separated from the abdomen by a deep constriction and bears four pairs of walking legs The abdomen is not segmented The head bears several simple eyes but nothing like the compound eyes of the insect Also it does not bear antennæ The ability to spin a web is a characteristic feature of the spider Spiders, being soft-bodied, are rarely preserved as fossils, but specimens found in the Lower Devonian rocks of Scotland are among the most ancient records of land animals

The *eurypterids* or "sea scorpions" (Figs 122, 123, pp 199, 200) were a remarkable race of large aquatic arachnids closely resembling the scorpions in bodily form Indeed, they were almost certainly the direct ancestors of the scorpions The eurypterids were confined to the water, and chiefly marine waters, and their limbs were partially modified into swimming paddles They were relatively large, the average length being several inches One form, *Pterygotus*, from the Silurian rocks of New York State, had a length of about 9 feet and ranks as the largest arthropod of all time The eurypterids are common and striking fossils in certain middle Paleozoic formations, but the race died out before the close of the Paleozoic era

*Trilobites* (pronounced *trī'lô bīte*) formed a primitive but exceedingly important group of arachnids which is now extinct and is known

only as fossils from the Paleozoic rocks In these the body was depressed and distinctly divisible into head, thorax, and tail (Fig 82, p 143) Head and tail were each covered by an unsegmented shield, but the thorax was jointed The entire body was longitudinally trilobed by reason of a pair of grooves that separated a rounded central axis from the lateral areas *This trilobation is* at once *the most distinctive feature of the group* and the one which gave it the name *Trilobita*[1]

The trilobites usually possessed a pair of compound eyes and a pair of antennæ or feelers Each body segment bore a pair of legs, and these were essentially alike from head to tail Each leg consisted of two branches, the lower one of which was a jointed limb for crawling, while the upper and outer branch was a delicate, feather-like structure, commonly regarded as a gill

### *Phylum Vertebrata*

The most advanced of all animals are those possessing a vertebral column or backbone So important is this phylum that it is often contrasted with all the other animals, which are known collectively as *invertebrates* The vertebrates are characterized by the highly organized character of their nervous system, with the spinal cord running along the dorsal side of the body, and by many other important details, but *the possession of a backbone is the most obvious and distinctive character* There are eight distinct classes, as follows: *fishes* (four classes), *amphibians, reptiles, birds*, and *mammals*

**Fishes.** Fishes are *primitively aquatic, cold-blooded vertebrates that breathe by means of gills* Most of them possess paired lateral fins as well as a tail fin

This is an enormous and highly diversified group with a long geologic record and, although commonly treated as a single class, is now subdivided into four distinct classes Many are scaled, but several of the extinct groups bore an armor of bony plates and some (for example, the catfish) are not protected by either scales or bone The skeleton is made of bone in the majority of modern fishes, but in most of the early groups it consisted of cartilage, as in the modern sharks and sturgeon

It is important to distinguish between the fishes, which are primitively adapted to life in the water and breathe by means of gills, and, on the other hand, certain fishlike animals that have returned from the land to become secondarily adapted to the water Among the latter are whales, porpoises, and seals, and certain extinct reptiles

(ichthyosaurs, plesiosaurs, and mosasaurs) These secondarily aquatic animals breathe only by means of lungs and must come to the surface for air They mimic fish but are not closely related to them

**Amphibia.** The frogs and salamanders constitute a class of vertebrates that are only partially adapted to life on the land and have many features to remind us of a fishlike ancestry Indeed, they are certainly the most primitive class of land vertebrates, and they clearly evolved from fishes The salamander is a typical representative of

Fig 348 A typical reptile, the Florida alligator

the class (the frog being a modern and extremely specialized form) Because its members live partly in water and partly on land, the class has received the name Amphibia (Gr *amphi*, on both sides, + *bios*, life) *The metamorphosis from an aquatic youth (tadpole) to a terrestrial adult life distinguishes amphibians from all other land animals* (Fig 35, p 61)

**Reptiles** The reptiles constitute a very large class of vertebrates and one that for long geologic ages completely dominated the Earth The group includes the alligators (Fig 348), crocodiles, lizards, turtles, and snakes, and the extinct dinosaurs and pterosaurs The crocodile is a very typical reptile

Reptiles are cold-blooded, egg-laying animals In shape, many of them closely resemble an amphibian, but they all differ from the amphibians in the way the young develop The reptile lays its eggs on the land, that is, out of the water These are provided with stored-up food in the form of yolk so that the young can develop fully enough

to crawl about and care for themselves immediately upon hatching. In other words, the reptiles are completely adapted for terrestrial life.

Although united by such features as their cold blood, their egg-laying habit, and various details of skeletal structure, the many different stocks of reptiles specialized greatly, some returned secondarily to aquatic life, and one group, the extinct pterosaurs, had wings.

**Birds.** The birds constitute a very well-defined class of vertebrates characterized by the presence of feathers and warm blood and by the egg-laying habit. In them the front limbs are specialized as wings. The birds diverged from one group of reptiles at about the same time the mammals were developing from another.

**Mammals.** The mammals are warm-blooded. They bring forth their young alive and nourish them with milk. All of them bear hair, though in some, as the whale and the elephant, the hair is almost lost through specialization. They constitute the dominant group of land animals of the Cenozoic and modern worlds, and some (seals, porpoises, and whales) have secondarily returned to the sea.

One small aberrant group, the monotremes, lays eggs. Two living genera are believed to represent an ancient, primitive stock of the mammals, but no paleontological record of this group is known.

The mammals did not appear on the Earth until Mesozoic time, and there is clear evidence that the ancestral types descended from one of the primitive groups of reptiles.

## Plants

A Simple Classification of the Plant Kingdom (after Berry, 1920)

Phylum **Thallophyta**—bacteria, fungi, seaweeds, etc.
Phylum **Bryophyta**—moss plants
Phylum **Pteridophyta**—ferns
Phylum **Arthrophyta**—scouring rushes, *calamites, sphenophylls*
Phylum **Lepidophyta**—club mosses, "ground pine," *lepidodendrons, sigillarias*
Phylum **Pteridospermophyta**—*seed ferns*
Phylum **Cycadophyta**—cycads, *williamsoniellas, cycadeoids*
Phylum **Coniferophyta** (gymnosperms)—*cordaites,* pines, sequoias, gingkos
Phylum **Angiospermophyta**—flowering and fruiting plants, hardwood trees, etc.

### *Phylum Thallophyta*

Plants of simple structure, such as bacteria, fungi, and seaweeds, are embraced for convenience in a single phylum, the Thallophyta (Gr

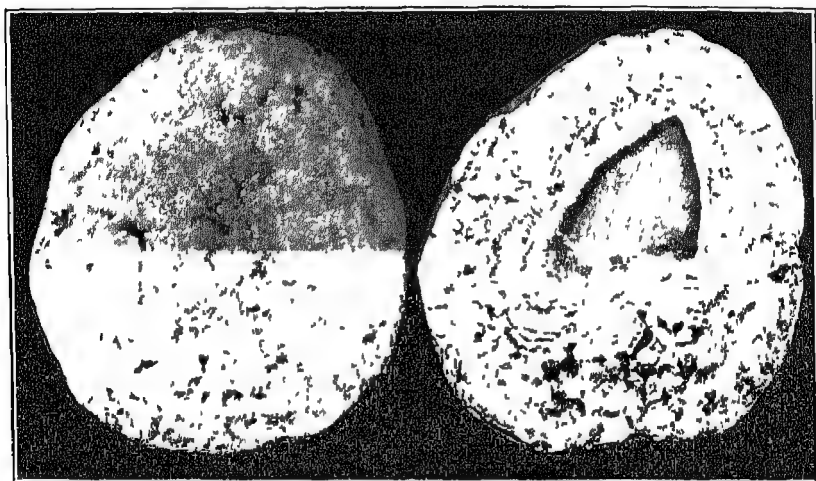
*thallos*, young shoot, + *phyton*, plant), so named because of their soft, nonwoody nature The *bacteria* are single-celled, microscopic, and soft-tissued *Diatoms* are aquatic plants, likewise single-celled and microscopic, which live in vast numbers near the surface of the seas and lakes and form one of the chief sources of food for all the marine animals They secrete delicate siliceous shells which accumulate over large areas of the modern ocean floor as *diatom ooze*

*Yale Peabody Museum*

FIG 349 Calcareous algæ A "water biscuit" from the bed of Little Conestoga Creek, near Philadelphia, Pennsylvania Left, external view of the colony, right, a median section showing the concentric laminæ of algal deposit about an angular pebble Slightly less than natural size

Plants probably evolved in the water and developed there for long ages before they could adjust themselves to the conditions upon the land This is inferred, at least, from the fact that nearly all the thallophytes are still aquatic plants Some of the seaweeds attain a length of 100 feet, but, regardless of size, these plants have no woody tissue and no circulatory system, for they lack the vascular tissue that serves to conduct the sap in higher plants and at the same time forms woody growth It is for this reason that they can not successfully leave the water All those forms that do live on land, such as fungi and lichens, are small, and grow only where there is considerable moisture All the thallophytes have a simple system of reproduction by means of spores

Most of the thallophytes are poorly adapted for preservation as fossils A number of types of the algæ, however, cause the precipitation of calcium carbonate, which settles over them to form a limy deposit Figure 349 shows such a deposit (a "water biscuit") formed by a mold-like colony of microscopic blue-green algæ that covered a pebble in a stream bed The deposit has a finely laminated texture due to the addition of concentric films of the calcium carbonate Similar limy deposits (Figs 71, 72, pp. 124, 125) occur in rocks of all ages as far back as the Archeozoic, and include the very earliest direct evidence of life on the Earth

The calcareous algæ play a very important role in the formation of modern "coral reefs," commonly depositing as much as 25 per cent of the reef

### *Phylum Bryophyta*

This small phylum, including the mosses and liverworts, represents the simplest stage of adaptation to land life Like the thallophytes, these plants lack vascular tissue, hence remain very small and thrive only in moist places Almost nothing is known of them as fossils

### *Phylum Pteridophyta*

The great tribe of the ferns constitutes the phylum Pteridophyta (Gr *pteris*, fern) They are the simplest of plants to be well adapted to land life They have well-developed vascular tissue and are differentiated into roots, stem, and leaves Whereas many of the ferns are small and herbaceous, the tree ferns of the tropics have woody trunks and commonly reach a height of 20 to 50 feet, bearing a crown of large fronds Ferns are distinguished above all else by the fact that *they reproduce by means of spores borne on the under sides of the leaves or on slightly modified leaves,* never in cones

Ferns are among the oldest fossil land plants known, being recorded first in the Lower Devonian rocks They have been a prolific tribe in all subsequent ages

### *Phylum Arthrophyta*

The scouring rushes and their kind constitute a well-defined tribe characterized by regularly jointed stems, whence the name (Gr *arthron,* joint). The existing horsetail or scouring rush (*Equisetum*) grows abundantly in moist places in many parts of the country In all the arthrophytes the stem has only a thin cylinder of woody tissue

around a large center of pith Reproduction is by means of spores which are borne in strobili (cones) at the tops of the stems.

Modern arthrophytes are mostly small, and the race is decadent, having passed its climax in the late Paleozoic, when giant scouring rushes (calamites) grew to the height of trees and had stems as much as 12 inches in diameter (Figs 165, 166, pp 268, 269)

### *Phylum Lepidophyta*

The *scale trees* or lepidophytes (Gr *lepis*, scale) constitute another well-defined tribe of plants that occupy a humble place in the modern world but were very important in the Paleozoic forests (Figs 165, 166, pp 268, 269) The ground pines or club mosses are modern examples Like the arthrophytes, these plants bear spores in strobili at or near the tips of the stems

Many of the Paleozoic species attained the size of forest trees In these the leaves, when shed, left prominent scars regularly spaced over the bark of the trunk and limbs (Fig 167, p 270) The name lepidophyte refers to these characteristic markings

### *Phylum Pteridospermophyta*

The oldest and most primitive seed-bearing plants were fernlike in everything but their fruit, whence the name (Gr *pteris*, fern, + *sperma*, seed) They are commonly known as *seed ferns*

The distinction between the spore-bearing and seed-bearing plants is comparable to that between the egg-laying and the viviparous animal, both in its nature and in its significance. The egg is a simple cell, deposited to hatch into an embryo that must look out for itself at a very immature stage of its development, the spore, likewise, is a single cell cast free to generate and grow as best it can On the other hand, the viviparous animal retains the egg in the mother's body until it has developed into an embryo of considerable complexity before birth liberates it to shift for itself Similarly, the seed is an embryo plant formed after the fertilization of the ovum, which is retained and nourished by the mother plant until considerable size has been attained and food is stored up to give the new plant a good start in life The development of seed is a very considerable specialization That it was an obvious advantage is suggested by the dominance of seed-bearing plants on the modern lands

The seed ferns were common from the late Devonian to the end of the Paleozoic, when they died out, having given rise meanwhile to other phyla of seed-bearing plants

*Phylum Cycadophyta*

The living sago palms or cycads represent an extensive tribe, mostly extinct, which has particular interest as the probable connecting link between the seed ferns and all higher plants, especially the true flowering plants (angiosperms) It is a great phylum, divisible into two well-marked orders, the one (*Cycadeoidea*) entirely extinct, and the

Fig 350 Stems, foliage, and flowers of the cycadeoid, *Williamsonia* Lower Jurassic of Mexico Natural size

other (*Cycadales*) represented by the modern cycads The cycads (Fig 217, p 347) possess short trunks and large pinnate leaves, and bear seeds in loose cones The trunk is heavily armored with persistent leaf bases

The cycadeoids (of late Paleozoic [?] and Mesozoic age) bore conspicuous flowers They were of two chief types, one stocky, like the modern cycads, and the other slender and branching The branched cycadeoids are of the greater interest from the evolutionary point of view They possessed rather slender stems bearing flowers at forks (Fig 350) It is believed that these plants developed from seed ferns and on the one hand evolved into the thick-bodied cycadeoids and on the other were at least closely allied to the early angiosperms This

group of cycadophytes is abundantly represented in the Triassic and Jurassic and probably was present in the late Paleozoic.

### *Phylum Coniferophyta*

The conifers constitute another great tribe of rather primitive seed plants characterized by the development of cones and, generally, by evergreen foliage. The leaves are as a rule needle-like or straplike and have parallel veins. There are several orders The pines are typical

The oldest group of conifers is the *cordaites*, which were common in the forests from Devonian to Permian time Unlike the later conifers, they had large, straplike leaves, and their seeds were loosely arranged in racemes instead of cones

Other groups, including the pines, araucarians, and gingkos, are known throughout the Mesozoic and later periods

### *Phylum Angiospermophyta*

The most advanced of all plants are the hardwood trees and the true flowering plants, included in the phylum Angiospermophyta, of which at least 125,000 kinds have been described They are all, of course, seed-bearing, but show a great advance over the other seed-bearing phyla in that their seeds are protected in a closed capsule or ovary For this reason they are known as angiosperms (covered seed) in contradistinction to the gymnosperms (naked seed), which include the seed ferns, conifers, and cycads.

The angiosperms are commonly characterized as *the flowering plants*, but this is hardly justified, since even the conifers and cycadophytes have flowers of a sort, and many of the latter had large and complicated flowers probably rivaling in size and brilliance the best of the angiosperms

The angiosperms are first identified in the Lower Cretaceous rocks, where the characteristic net-veined leaves of deciduous trees make their appearance

## References

[1] *Studies on Trilobite Morphology*, by Leif Størmer Norsk geol tidsskrift Pt 1 in Vol 19, 1939, pp 143–273, Pt 2 in Vol 21, 1942, pp 49–164

Dr Størmer presents convincing evidence that trilobites are related to arachnoids rather than to crustaceans

## Collateral Reading

*Animals without Backbones*, by Ralph Buchsbaum 405 pages University of Chicago Press, Chicago Revised ed, 1948

Superbly illustrated

*Animals of the Land and Sea;* by Austin H Clark 276 pages Chapman and Hall, London, 1926

A Scientific Book of the Month Club volume

*Prehistoric Life*, by Percy E Raymond 324 pages Harvard University Press, 1939

*Plant Life through the Ages*, by A C Seward 597 pages The Macmillan Co, New York and London, 1931

A scholarly review of the structure, relationships, and geologic history of fossil plants

*Tree Ancestors, a Glimpse into the Past;* by E W Berry 270 pages Williams and Wilkins, Baltimore, 1923

*Paleobotany A Sketch of the Origin and Evolution of Floras;* by E W Berry Smithsonian Report for 1918 (1920), pp 289–407

*Handbook of Paleontology for Beginners and Amateurs Part I The Fossils*, by Winifred Goldring 356 pages New York State Museum, Handbook 9, 1929

*Vertebrate Paleontology*, by Alfred S Romer, 687 pages University of Chicago Press, Chicago 2d ed, 1945

*Man and the Vertebrates*, by Alfred S Romer 405 pages University of Chicago Press, Chicago 3d ed, 1941

Entertaining and well illustrated

*Foundations of Biology*, by Lorande L Woodruff 773 pages The Macmillan Co, New York 6th ed, 1941

## Appendix B

# CORRELATION TABLES

The following tables indicate the age relations of selected rock formations. Horizontal lines mark beds of equivalent age. The space allotted to a rock unit indicates the relative time it represents, and has little relation to actual thickness. Vertical shading indicates a hiatus.

| Series | Central Appalachians | Southern Appalachians | Upper Miss Valley | East-central Nevada | Central Wyoming | Canadian Rockies |
|---|---|---|---|---|---|---|
| Croixian | Conococheague ls: Gatesburg f<br>Warrior f | Copper Ridge dol<br>Maynardsv ls<br>Nolichucky sh | Trempeleau stage<br>Franconia stage<br>Dresbach stage | Mendha ls | Boysen f: Grove Cr member<br>Snowy Range member<br>Maurice member | Goodsir f<br>Sabine f<br>Bosworth f |
| Albertan | Elbrook f | Conasauga sh: Maryville ls<br>Rogersville sh<br>Rutledge ls | | Highland Pk<br>Burrows dol<br>Peasley ls<br>Chisholm sh<br>Lyndon ls<br>Comet sh | DePass f: Gros Ventre member<br>Flathead m | Eldon dol<br>Stephens f<br>Cathedral d<br>Ptarmigan f |
| Waucobian | Waynesboro f<br>Tomstown dol<br>Antietam qtz | Rome f<br>Shady dol<br>Weisner qtz | | Pioche sh<br>Prospect Mt qtz | | Mt Whyte f<br>St Piran ss |

Table 1 Cambrian Formations.

| Series | New York State | Central Appalachians | Central States | Western States |
|---|---|---|---|---|
| Cincinnatian | Queenston sh<br>Oswego ss<br>Pulaski sh<br>Whetstone Gulf sh | Juniata ss<br>Bald Eagle congl<br>"Oswego" ss<br>Reedsville sh<br>Martinsburg sh | Richmondian stage<br>Maysvillian stage<br>Eden sh. | Bighorn dol |
| Champlainian | Utica sh<br>Trenton ls — Canaj sh<br>Chaumont ls<br>Lowville ls<br>Pamelia ls<br>Chazy ls | Coburn ls<br>Salona ls<br>Nealmont ls<br>Hunter ls — Edinburg ls<br>Hatter ls<br>Lincolnshire ls<br>N Market ls — Blackford | Viola ls — Galena dol<br>Simpson gr: Bromide ls; Tulip Cr f; McLish f; Oil Cr f; Joins f<br>St Peter ss | Eureka qtz<br>Swan Pk qtz |
| Canadian | Beekmantown dol and ls<br>Deepkill sh | Bellefonte dol<br>Axeman ls<br>Nittany dol<br>Stonehenge ls — Chepultepec ls<br>"Beekmantown" dol | Black Rock ls<br>Smithville ls<br>Powell dol<br>Cotter dol<br>Theodosia f<br>Roubidoux f<br>Gasconade dol<br>Arbuckle ls | Ellenberger<br>El Paso ls<br>Garden City ls |

TABLE 2 Ordovician Formations

| Series | New York State | Great Lakes Region | Central Appalachians | Ohio and Tenn Valleys |
|---|---|---|---|---|
| Cayugan | Manlius group<br>Cobleskill ls<br>Salina group: Bertie ls; Camillus sh and salt; Vernon sh | Bass Id group<br>Salina sh | Keyser group<br>Tonoloway ls<br>Wills Creek sh<br>Bloomsburg redbeds | |
| Niagaran | Guelph dol<br>Lockport dol<br>Clinton group: Rochester sh; Irondequoit ls; Reynales ls; Thorold ss | Guelph dol<br>Engadine (Racine) dol<br>Manistique dol<br>Burnt Bluff gr: Hendrix dol; Byron dol | McKenzie f<br>Clinton group: Rochester sh; Keefer ss; Rose Hill sh | Huntington dol — Peebles<br>Durbin<br>Louisville — Brownsport<br>Osgood — St Clair |
| Medinan | Grimsby (Albion) ss<br>Cabot Head sh<br>Whirlpool ss | Mayville dol<br>Cabot Head sh<br>Manitoulin dol | Tuscarora ss<br>Shawangunk congl | Brassfield ls |

TABLE 3 Silurian Formations

TABLE 4 Devonian Formations

| Series | Mississippi Valley | Ozark Region | Appalachian Region | Cordilleran Region |
|---|---|---|---|---|
| Chesterian | Elvira gr: Kinkaid ls, Tar Spr ss; Homburg gr: Glen Dean ls, Hardinsburg ss, Golconda f, Cypress Cr ss; New Design gr: Paint Cr f, Yankeetown chert, Renault f, Aux Vases ss | Pitkin ls; Fayette sh; Batesville ss | Bluestone gr; Princeton ss; Hinton gr; Bluefield gr; Greenbriar gr; Mauch Chunk gr | Manning Canyon sh; Great Blue ls |
| Meramec | Ste Genevieve ls; St Louis ls; Spergen ls; Warsaw ls | Moorefield sh | Maccrady gr | Humbug ls; Deseret ls |
| Osagian | Keokuk ls; Burlington ls; Fern Glen ls; Boone ch | Boone chert; St Joe ls | Price gr; Pocono gr | Madison ls; Leadville ls; Redwall ls |
| Kinderhook | Choteau ls; Maple Mill sh; Louisiana ls; Saverton sh; Sulphur Spr f | Chattanooga sh; Sylamore ss | Chattanooga sh | |

TABLE 5 Mississippian Formations

| Series | Mid Continent: Kansas | Mid Continent: Oklahoma | Mid Continent: Texas | Illinois & Kentucky | Appalachian Region |
|---|---|---|---|---|---|
| Virgilian | Wabaunsee gr<br>Shawnee gr<br>Douglas gr | Vanoss f<br>Ada f<br>Vamoosa f | Cisco: Thrifty gr<br>Graham gr | | Monongahela: Waynesboro coal<br>Pittsburgh coal |
| Missourian | Pedee gr<br>Lansing gr<br>Kansas City gr<br>Pleasanton gr | Ochelata f<br>Francis f<br>Seminole ss | Canyon: Caddo Cr gr<br>Graford gr<br>Whitt gr | McLeansboro: La Salle ls<br>Lonsdale ls | Conemaugh: Ames ls<br>Brush Cr. ls |
| Desmoinesian | Marmaton gr<br>Cherokee sh | Holdenville f<br>Wewoka f<br>Wetumka sh<br>Boggy f<br>Savanna f | Strawn: Lone Camp<br>Millsap Lake gr | Carbon: Herrin coal<br>Stonefort ls<br>Tradewater | Allegheny: U Freeport ls<br>Clarion coal<br>Pottsville: Brookville coal<br>Kanawah gr |
| Atokan | | McAlester sh<br>Hartshorne ss<br>Atoka f | Lampasas: Smithwick gr<br>Big Saline gr | Tradewater: Seville ls | Pottsville: Kanawah gr |
| Morrowan | | Wapanucka ls<br>Johns Valley sh<br>Jackfork ss<br>Stanley sh | Morrow: Marble Falls ls | Caseyv | Pottsville: New River gr<br>Pocahontas gr |

TABLE 6 Pennsylvanian Formations

| Series | Glass Mts Texas | Guadalupe Basin Texas | Grand Canyon | Wyoming | Central Texas |
|---|---|---|---|---|---|
| Ochoan | Tessey ls | Dewey Lake redbeds<br>Rustler dol + anhydrite<br>Salado halite<br>Castile anhydrite | | | |
| Guadalupian | Gilliam ls<br>Capitan reef<br>Altuda f<br>Vidrio member<br>Word f | Delaware Mt gr: Bell Canyon f<br>Cherry Canyon f<br>Brushy Canyon f<br>Capitan reef<br>Carlsbad ls<br>Chalk Bluff f<br>Goat Seep reef | | Phosphoria f<br>Chugwater redbeds | Whitehorse group |
| Leonardian | Leonard f<br>Hess facies | Cutoff sh<br>Victoria Peak gray ls<br>Bone Spring ls (black ls) | Kaibab ls<br>Toroweap ls<br>Coconino s<br>?<br>Supai f. | | Pease R gr: Blaine gyp<br>Clear Fork gr: Choza f<br>Vale f<br>Arroyo f |
| Wolfcamp | Wolfcamp f. | Hueco ls | Supai f.<br>? | Cassa gr<br>Lyons<br>Owl Cr | Wichita gr: Belle Pl<br>Admiral f<br>Putnam f<br>Moran f<br>Pueblo f |

TABLE 7 Permian Formations

| Series | European stages: Alps | European stages: Germany | Appalachian Region | Colorado Plateau | Wyoming | Central Nevada | California | West Canada |
|---|---|---|---|---|---|---|---|---|
| Upper Triassic | Rhaetian | | | | | | | |
| | Norian | Keuper series | Newark gr | Chinle f | | Gabbs f | Brock sh | Schooler Cr f; Pardonet |
| | Karnian | | | | | Luning f | Hosselkus ls | Gray m |
| Middle Triassic | Ladinian | | | | | | Pit sh | |
| | Anisian | Muschel-kalk ser | | | | Excelsior f | | Spray River f; Whitehorse m |
| L Triassic | Scythian | Bunter series | | Moenkopi f | Upper Chugwater sh; Dinwoody f | Candelaria | Dekkas volcanics | Sulphur Mt |

TABLE 8 Triassic Formations

| Series | European Stages | Wyoming | Colorado Plateau | Alberta and BC | Central Oregon | California |
|---|---|---|---|---|---|---|
| Upper Jurassic | Purbeckian | | | | | Knoxville gr |
| | Portlandian | | | | Lonesome f | Franciscan gr |
| | Kimmeridgian | Morrison f | Morrison f | | | Mariposa sl |
| | Corallian | | San Rafael gr: Summerville f | | | |
| | Oxfordian | Sundance f | Curtis f | | | |
| | Callovian | | Entrada ss; Carmel f | | Trowbridge f | |
| Middle J | Bathonian | | | Fernie sh | | |
| | Bajocian | Gypsum Spr f | | | Izee gr; Colpitts gr | |
| Lower Jurassic | Toarcian | | Glen Canyon gr | | | |
| | Pliensbachian | | Navajo ss | | Mowich gr | |
| | Sinemurian | | | | | |
| | Hettangian | | Kayenta f; Wingate ss | | | |

TABLE 9 Jurassic Formations

| Series | European stages | Texas | Western Interior | East Gulf Coast | Atlantic Coast |
|---|---|---|---|---|---|
| Upper Cretaceous | | | Laramie group | | |
| | Maestrichtian | Navarro gr | Montana group: Fox Hills ss; Bearpaw sh | Ripley sh | Monmouth gr |
| | Campanian | Gulf series: Taylor gr | Montana group: Belly R f (Judith R f, Claggett sh, Eagle ss); Pierre sh | Selma chalk | Matawan gr |
| | Santonian | | | Coffee ss | |
| | Coniacian | Austin chalk | Colo gr: Niobrara chalk | Eutaw f | Magothy f |
| | Turonian | Eagle Ford sh | Colo gr: Benton sh | | |
| | Cenomanian | Woodbine ss | Dakota ss | Tuscaloosa f | Raritan f |
| Lower Cretaceous | | | Fuson sh | | |
| | Albian | Comanche series: Washita gr; Fredericksburg gr | Lakota ss | | Patapsco f |
| | Aptian | Trinity gr | | | |
| | Barremian | | | | Arundel f |
| | Hauterivian | | | | |
| | Valangian | | | | Patuxent f |
| | Berriasian | | | | |

TABLE 10 Cretaceous Formations

| Series | Northern Great Plains | Wyoming | N Mex. | Atlantic Coast | Gulf Coast | California |
|---|---|---|---|---|---|---|
| Pleis | | | | | | Tulare f |
| Pliocene | Ogallala gr; Snake Creek beds | | Santa Fe | Yorktown f | Citronelle f | San Joaquin f; Etchegoin f; Jacalitos f |
| Miocene | Hemingsford gr; Arikaree gr; Rose Bud | | | St Marys f; Choptank f; Calvert f | Pascagoula; Hattiesburg; Catahoula ss | San Pablo gr; Monterey; Temblor f |
| Oligocene | White River gr: Brule clay; Chadron | Wiggins f | | | Vicksburg gr | Kreyenhagen sh |
| Eocene | | Uinta f; Bridger f; Green R; Wind R; Wasatch | | Pamunkey: Woodstock; Aquia Cr f | Jackson gr; Claiborne gr; Wilcox gr | Domengine f |
| Paleocene | Ft Union gr | Polecat Bench: Clark Fork f; Silver Coulee; Rock Bench f; ?; Mantua beds | Tiffany f; Torrejon f; ?; Puerco f | | Midway gr: Porters Cr f; Clayton f | Martinez gr: Meganos gr |

TABLE 11 Cenozoic Formations

# INDEX

(Asterisks refer to illustrations)